

VENANGO COUNTY REGIONAL PLANNING COMMISSION

Venango County
Act 167 County-Wide
Stormwater Management Plan
Phase II

June 22, 2010



[BUILDING RELATIONSHIPS.
DESIGNING SOLUTIONS.]

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**VENANGO COUNTY
ACT 167 PLAN PHASE II**

ACKNOWLEDGEMENTS

The Venango County Regional Planning Commission would like to thank the following individuals, municipalities, and agencies for their assistance and support of this project:

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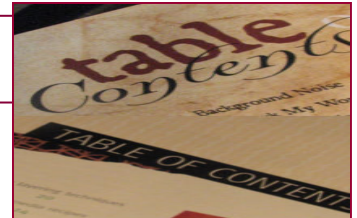
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Part II

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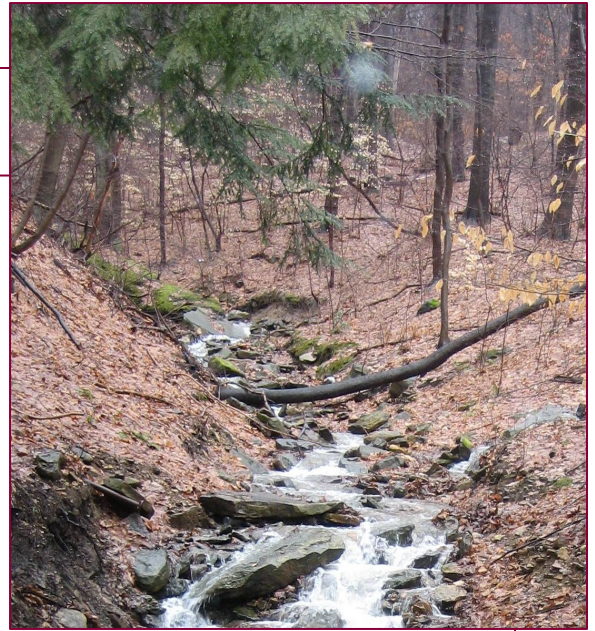
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Section I – Introduction

This stormwater management plan is the product of a collaborative effort between the varied stakeholders located in the Act 167 Designated Watersheds in Venango County, Pennsylvania. The Plan has been developed based on the requirements of the *Pennsylvania Stormwater Management Act*, Act 167 of 1978 and guidelines established by the Pennsylvania Department of Environmental Protection (DEP). The intent of this document is to present the findings of a two-phased multi-year study of the watersheds in the county. Generally, the study was undertaken to develop recommendations for improved stormwater management practices, to mitigate potential negative impacts by future land uses, and to improve conditions of impaired waters. The specific goals of this plan are discussed in detail in the following section.

This section introduces some basic concepts relating the physical elements of stormwater management, the hydrologic concepts, and the planning approach used throughout this study.



RAINFALL AND STORMWATER RUNOFF

Precipitation that falls on a natural landscape flows through a complex system of vegetation, soil, groundwater, surface waterways, and other elements as it moves through the hydrologic cycle. Natural events have shaped these components over time to create a system that can efficiently handle stormwater through evaporation, infiltration, and runoff. The natural system often sustains a dynamic equilibrium, where this hydrologic system evolves due to various ranges of flow, sediment movement, temperature, and other variables. Alterations to the natural landscape change the way the system responds to precipitation events. These changes often involve increasing impervious area, which results in decreased evaporation and infiltration and increased runoff. The increase in stormwater runoff is manifested in runoff quantity, or volume, and runoff rate. These two factors cause the natural system to change beyond its natural dynamic equilibrium, resulting in negative environmental responses such as accelerated erosion, greater or more frequent flooding, increased nonpoint source pollution, and degradation of surface waters. Decreased infiltration means less groundwater recharge which in turn leads to altered dry weather stream flow.

Some level of stormwater runoff occurs as the infiltrative capacity of the surface is exceeded. This occurs even in undisturbed watersheds. However, the volume and rate of runoff are substantially increased as land development occurs. Stormwater management is a general term for practices used to reduce the impacts of this accelerated stormwater runoff. Stormwater management practices such as detention ponds and infiltration areas are designed to mitigate the negative impacts of increased runoff. Volume of runoff and rate of runoff are often referred to by the term “water quantity”. Water quantity controls have been a mainstream part of stormwater management for years. Another aspect of runoff is water quality. This refers to the physical characteristics of the runoff water. Common water quality traits include temperature, total suspended solids, salts, and dissolved nutrients. Water quality is an emerging topic in stormwater management and the general water resources field. Both water quantity and water quality can contribute to degradation of surface waters.

Section I – Introduction

As development has increased, so has the problem of managing the increased quantity of stormwater runoff. Individual land development projects are frequently viewed as separate incidents, and not necessarily as an interconnected hydrologic and hydraulic system. This school of thought is exacerbated when the individual land development projects are scattered throughout a watershed (and in many different municipalities). However, it has been observed and verified that the cumulative nature of individual land surface changes dramatically influences flooding conditions. This cumulative effect of development in some areas has resulted in flooding of both small and large streams, with substantial financial property damage and endangerment of the public health and welfare. Therefore, given the distributed and cumulative nature of the land alteration process, a comprehensive (i.e., watershed-level) approach must be taken if a reasonable and practical management and implementation approach or strategy is to be successful.

Watersheds are an interconnected network in which changes to any portion of the watershed carry throughout the system. There are a variety of factors that influence how runoff from a particular site will affect the overall watershed. Many of the techniques for managing stormwater in a watershed are unique to each watershed. An effective stormwater management plan must be responsive to the existing characteristics of the watershed and recognize the changing conditions resulting from planned development. In Pennsylvania, stormwater management is generally regulated on the municipal level, with varying degrees of coordination on types and levels of stormwater management required between adjoining municipalities. A watershed-based stormwater management plan can minimize inconsistencies to more effectively address the issues which contribute to a watershed's degradation. While land use regulation remains at the municipal level, the framework established within a watershed plan enables municipalities to see the impact of their regulations on the overall system and coordinate their efforts with other stakeholders in the watershed.

WATERSHED HYDROLOGY

Under natural conditions, watershed hydrology is in dynamic equilibrium. That is, the watershed, its ground and surface water supplies, and resulting stream morphology and water quality evolve and change with the existing rainfall and runoff patterns. This natural state is displayed by stable channels with minimal erosion, relatively infrequent flooding, adequate groundwater recharge, adequate base flows, and relatively high water quality. When all of these conditions are present the streams support healthy, diverse and stable in-stream biological communities. The following is a brief discussion of the impact of development on these stream characteristics:

1. Channel Stability – In an undisturbed watershed, the channels of the stream network have reached an equilibrium over time to convey the runoff from its contributing area within the channels banks. Typically, the channel will be large enough to accommodate the runoff from a storm with a magnitude that will occur approximately every 18-24 months. Disturbances such as development in the watershed disrupt this equilibrium. As development occurs, additional runoff reaches the streams more frequently. This results in the channel becoming unstable as it attempts to resize itself. The resizing occurs through bed and bank erosion, altered flow patterns, and shifting sediment deposits.
2. Flooding – When a watershed is disturbed and channel instability occurs, it results in increased localized flooding and other associated problems. Overbank flows will occur more frequently until the channel reaches a new equilibrium. It is important to realize that this equilibrium may take many years to be attained once the new runoff patterns are in place. In watersheds with continuous development, a new equilibrium may not be reached. Additionally, floodplain encroachment and in-stream sediment deposits from channel erosion may exacerbate flooding.

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3. **Groundwater Recharge** – In an undisturbed watershed, runoff is minimal. Natural ground cover, undisturbed soils, and uneven terrain provide the most advantageous conditions for maximum infiltration to occur. When development occurs, these favorable conditions are diminished or removed, causing more rainfall to become runoff that flows to receiving streams instead of infiltrating. Less water is retained in the watershed to replenish groundwater supplies.
4. **Base Flows** – Loss of groundwater recharge, as described above, leads to insufficient groundwater available to replenish stream flow during dry weather. As a result, streams that may have an adequate base flow during dry weather under natural conditions may experience reduced flow or become completely dry during periods of low precipitation in developed watersheds. Thermal degradation of the waterbody often accompanies the reduction of base flow originating from groundwater. This source of base flow is generally much cooler than surface water sources. The increase in water temperature can be detrimental to many ecological communities.
5. **Water Quality** – Stormwater from developed surfaces carries a wide variety of contaminants. Pesticides, herbicides, fertilizers, automotive fluids, hydrocarbons, sediment, detergents, bacteria, increased water temperatures, and other contaminants that are found on land surfaces are carried into streams by runoff. These contaminants affect the receiving streams in different ways, but they all have an adverse impact on the quality of the water in the stream.
6. **Stream Biology** – Biological communities reflect the overall ecological integrity of a stream. The composition and density of organisms in aquatic communities responds proportionately to stressors placed on their habitat. Communities integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions. The adverse impacts of improperly managed runoff and increased pollution are evident in the biological changes in impacted streams. When biological communities within a waterbody degrade, the overall ecological integrity of the stream is also diminishing.

It is important to understand that watershed hydrology, rainfall, stormwater runoff, and all of the above characteristics are interconnected. The implications of this concept are far reaching. How we manage our watersheds has a direct impact on the water resources of the watershed. Any decision that affects land use has implications on stormwater management and, in turn, impacts the quality of the available water resources. The quality of water resources has an economic consequence as well as an effect on the quality of life in the surrounding areas. This understanding is at the core of current stormwater management approaches.

The stormwater management philosophy of this plan is reflected in the required standards: peak flow management, water quality management, infiltration requirements, and channel protection requirements. The philosophy, and thus the standards, reflects an attempt to manage stormwater in such a way as to maintain the watershed hydrology as near to existing or historical conditions as possible. Maintaining watershed hydrology is essential to maintaining the water resources of the watershed.

STORMWATER MANAGEMENT PLANNING

Historically, the approach to stormwater management was to collect the runoff and deliver it via a system of inlets and pipes as quickly as possible to the nearest receiving waters. The increased volume of stormwater delivered quickly to receiving waters had a detrimental effect on channel morphology. Negative impacts such as severe channel erosion and significant in-stream sediment deposits resulted. These impacts lead to unstable, deepened and widened channels, nuisance flooding, infrastructure damage, increased culvert and bridge maintenance requirements, and have a detrimental affect on the stream quality in terms of habitat for aquatic

Section I – Introduction

organisms. In addition, large amounts of rainfall are lost to the watershed and become unavailable for infiltration and groundwater recharge, and contaminants on the land surface enter the stream untreated. This approach cannot be considered stormwater management in any meaningful terms.

This approach was later replaced with the stormwater management standards that are currently in place in most municipalities. This more-recent approach requires that peak flows from development sites be managed, usually through detention ponds, such that the peak discharge from the site is no greater than 100% of the peak discharge rate from the site prior to development. While this may have helped reduce some stormwater problems, there were two significant failings with this approach.

The first failing of this approach is that it does not consider the watershed as a single interrelated hydrologic unit. An integrated watershed management approach is needed to overcome this situation. Two points are emphasized regarding the need for an overall watershed management approach:

1. Stormwater regulatory responsibility, absent arrangements to the contrary, rests with the municipal governments in Pennsylvania. Therefore, stormwater management regulations, if applied at all, are implemented by a municipality only within the boundaries of its own jurisdiction. There is no guarantee that all municipalities in a given watershed have comparable standards. When standards are implemented by individual municipalities the problems caused by unmanaged stormwater in an area with poor, or no, regulations are conveyed to municipalities downstream. Upstream municipalities often cause stormwater problems for downstream neighbors. In these situations, downstream municipalities are forced to deal with problems associated with increased water volume, increased sediment loads, and increased pollutants which originate in areas over which they have no control.
2. Each area within a watershed is unique in terms of its contribution to the overall watershed hydrology. When the same standards are implemented throughout a municipality, and the overall watershed hydrology is not considered, these standards can result in over-management in some areas and under-management in other areas. In some cases, this type of management could actually exacerbate stormwater problems. Further, this “one-size-fits-all” approach does not take into account conditions such as soil infiltration rates, slopes, or channel conditions, which vary throughout a watershed and municipality.

The second key failing is that this approach does not consider the aspects of water quality, channel protection, or the importance of infiltration in the hydrologic cycle. Simply managing the rate at which stormwater leaves a development site does not maintain the overall watershed hydrology. When implementing a peak rate control strategy as the sole method of controlling stormwater runoff, pollutants are still delivered to surface waters, rainfall is still unavailable to the watershed for recharge, and channel erosion and sedimentation still occur.

LOW-IMPACT DEVELOPMENT AND STORMWATER MANAGEMENT

Low-Impact Development (LID) is an approach to land development that uses various land planning and design practices and technologies to simultaneously conserve and protect natural resource systems and reduce infrastructure costs (HUD, 2003). As the term applies to stormwater management, LID is an approach to managing stormwater in a manner similar to nature by managing rainfall at the source using uniformly distributed, decentralized, micro-scale controls (Low Impact Development Center, 2007). These concepts are the origin of many of the strategies identified to achieve the goals presented in this Plan.

Section I – Introduction

As a comprehensive technology-based approach to managing stormwater, LID has developed significantly since its inception, in terms of policy implementation and technical knowledge. The goals and principles of LID, as describe in *Low-Impact Development Design Strategies* (Prince Georges County, 2000) are defined as follows:

- Provide an improved technology for environmental protection of receiving waters.
- Provide economic incentives that encourage environmentally sensitive development.
- Develop the full potential of environmentally sensitive site planning and design.
- Encourage public education and participation in environmental protection.
- Help build communities based on environmental stewardship.
- Reduce construction and maintenance costs of the stormwater infrastructure.
- Introduce new concepts, technologies, and objectives for stormwater management such as micromanagement and multifunctional landscape features (bioretention areas, swales, and conservation areas); mimic or replicate hydrologic functions; and maintain the ecological/biological integrity of receiving streams.
- Encourage flexibility in regulations that allows innovative engineering and site planning to promote smart growth principles.
- Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches.

The overall design concepts and specific design measures for BMPs are derived from the following conceptual framework (Prince Georges County, 2000):

1. The site design should be built around and integrate a site's pre-development hydrology;
2. The design focus should be on the smaller magnitude, higher frequency storm events and should employ a variety of relatively small Best Management Practices (BMPs);
3. These smaller BMPs should be distributed throughout a site so that stormwater is mitigated at its source;
4. An emphasis should be given to non-structural BMPs; and
5. Landscape features and infrastructure should be multifunctional so that any feature (e.g., roof) incorporates detention, retention, filtration, or runoff use.

The LID process is meant to provide an alternative approach to traditional stormwater management. *Table 1.1* highlights the difference between the two approaches. These concepts, as they apply to stormwater, are the basis for the stormwater management approach presented in this Plan.

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LID Approach		Traditional Approach	
Approach	Examples	Approach	Examples
1. Integration of Pre-Development Hydrology	A development built around a drainage way outside of functional floodplain	Elimination of all water features from project site	Redirection and conveyance of drainage; alteration of floodplain to meet site design
2. Emphasis on smaller magnitude, higher frequency storm events	Several small BMPs	Large stormwater ponds and facilities that focuses on 10 and 100-year events	A single stormwater pond
3. Stormwater to be mitigated at source	BMPs located near buildings, within parking lot islands	Stormwater to be conveyed to low point in site	A single stormwater pond
4. Use simple, non-structural BMPs	Narrower drive ways, conservation easements, impervious disconnection	Use of pipe and stormwater ponds	A single stormwater pond
5. Use of multifunctional landscape and infrastructure	Green roofs, rain gardens in parking lot islands	Stormwater and site feature kept as separate as possible	No consideration given

Table 10.1. Comparison of LID Versus Traditional Stormwater Management Approach

When implemented at the site level, LID has been found to have a beneficial impact on water quality and in reducing peak flows for more frequent storm events (Bedan and Clausen, 2009; Hood et. al., 2007). There are numerous case studies and pilot projects that emphasize similar findings about the benefits of site level development and of specific LID BMPs (EPA, 2000; DEP, 2006; Low Impact Development Center, 2009).

When implemented at the watershed level, as proposed in this Plan, there are quantifiable benefits in terms of reduced peak discharges coming from future developments (as discussed in *Section VI*). The approach of considering water quality and existing condition hydrology will help address documented stream impairments (as discussed in *Section IX*). Additionally, adopting a LID approach will help alleviate the economic impact of the additional regulations proposed in the model ordinance (as discussed in *Section VIII*). Several other Act 167 Plans that have been recently prepared or are being prepared concurrently with this Plan further support these findings.

Section II – Goals and Objectives of the Act 167 Stormwater Management Plan

STORMWATER PLANNING AND THE ACT 167 PROCESS

Recognizing the increasing need for improved stormwater management, the Pennsylvania legislature enacted the *Stormwater Management Act* (Act 167 of 1978). Act 167, as it is commonly referred to, enables the regulation of development and activities causing accelerated runoff. It encourages watershed based planning and management of stormwater runoff that is consistent with sound water and land use practices, and it authorizes a comprehensive program of stormwater management intended to preserve and restore the Commonwealth's water resources.

The Act designates the Department of Environmental Resources as the public agency empowered to oversee implementation of the regulations and defines specific duties required of the Department. The Department of Environmental Resources was abolished by Act 18 of 1995. Its functions were transferred to the Pennsylvania Department of Conservation and Natural Resources (DCNR) and the Department of Environmental Protection (DEP). Duties related to stormwater management became the responsibility of DEP (Act 18 of 1995).

As described in Act 167, each county must prepare and adopt a watershed stormwater management plan for each watershed located in the county, as designated by the department, in consultation with the municipalities located in each watershed, and each county shall periodically review and revise such plan at least every five years. Within six months following adoption and approval of the watershed stormwater plan, each municipality must adopt or amend and must implement such ordinances and regulations, including zoning, subdivision and land development, building code, and erosion and sedimentation ordinances, as are necessary to regulate development within the municipality in a manner consistent with the applicable watershed stormwater plan and the provisions of the Act.

Section 5 of Act 167 sets forth the Plan contents required for each Stormwater Management Plan. Section 5.b lists thirteen (13) elements to include in the Plan, and Section 5.c lists an additional two (2) elements for inclusion. The following table addresses these elements in Section 5 of Act 167, and present the necessary information to inventory and address issues with stormwater management in the County.



SECTION 5b

(1) A survey of existing runoff characteristics in small as well as large storms, including the impact of soils, slopes, vegetation and existing development;

Section 3 identifies and analyzes factors that impact the hydrologic response of the identified watershed for including existing and future land use conditions. Section 6 discusses the technical analysis performed on the on focused watersheds. The other watersheds within the County should be considered in future Plans. Appendix A details the modeling completed to perform the technical analysis. In addition, relevant details of the factors and elements impacting the hydrologic response of the watersheds are shown graphically in the Plates.

Section II – Goals and Objectives of the Act 167 Stormwater Management Plan

(2) A survey of existing significant obstructions and their capacities;

The municipalities, through the PAC, responded to a survey which compiled an inventory of obstructions. Section 5 provides the inventory as well as a discussion. Capacities of the obstructions were not fully developed as Budgetary impacts reduced the scope of the Plan. Plate 7 shows the identified obstructions.

(3) An assessment of projected and alternative land development patterns in the watershed, and the potential impact of runoff;

A hydrologic model was developed and used to assess the impacts future land development alternatives in order to address the potential impacts of increased runoff, as discussed in Sections 6 and 7 as well as Appendix A.

(4) An analysis of present and projected development in the flood hazard areas, and its sensitivity to damages from future flooding or increased runoff;

Federal flood insurance studies have been used as reference for the location of flood plain areas as identified in Plate 8. Section 3 provides a discussion and an analysis showing damages to existing development due to flood hazard areas caused by increased runoff in the watershed. Recommendations were made with measures to mitigate future damages in Section 7.

(5) Survey of existing drainage problems and proposed solutions;

The municipalities, through the PAC, responded to a survey which compiled an inventory of existing problem areas. Section 5 provides the inventory as well as a discussion. Plate 7 shows the identified problem areas as well as Appendix C.

(6) A review of existing and proposed stormwater collection systems;

The more urbanized areas of the County contain storm sewer systems, as do the many roadways that traverse the County. Storm sewer collection systems have a significant effect on the hydrologic response of a watershed as pipe networks rapidly increase runoff rate. If stormwater control facilities do not intercept runoff from storm sewer systems, flooding often increases, as well as other stormwater problems such as streambank erosion and sedimentation. Plate 7 shows the collection systems as identified by the municipalities through the PAC.

(7) An assessment of alternative runoff control techniques and their efficiency in the particular watershed;

Section 7 of the Plan identifies a variety of runoff control techniques are available for use in all watersheds in the County. It references and expands upon the Pennsylvania Stormwater Best Practices Manual to identify innovative methods of controlling runoff. In addition, traditional engineering solutions such as drainage structure replacement, streambank restoration, etc. were also identified in situations where alternative runoff controls are not applicable.

(8) An identification of existing and proposed state, federal and local flood control projects located in the watershed and their design capacities;

Section 3 lists the local, state, and federal flood control projects in the County which was shown on Plate 8. Where the effectiveness in mitigating flooding or design capacity data was readily available, this information was also documented.

(9) A designation of those areas to be served by stormwater collection and control facilities within a 10-year period, an estimate of the design capacity and costs of such facilities, a schedule and an identification of the existing or proposed institutional arrangements to implement and operate the facilities;

Stormwater control facilities were identified and documented by municipalities and through the completion of the Questionnaire. The data was compiled and tabulated for those municipalities which provided data. Sections 7 and 9 identify recommended strategies to address runoff impacts from future development.

(10) An identification of flood plains within the watershed;

Flood insurance studies prepared under the National Flood Insurance Program were identified in Section 3 and shown on Plate 8.

(11) Criteria and standards for the control of stormwater runoff from existing and new development which are necessary to minimize dangers to property and life and carry out the purposes of this act;

Standards and criteria were developed in Section 7 which are to be implemented through the Model Ordinance.

(12) Priorities for implementation of action within each plan; and

Section II – Goals and Objectives of the Act 167 Stormwater Management Plan

Section 11 details the preparation process completed and the County adoption of the draft Plan with submission to PADEP for approval. This will initiate the mandatory schedule of adoption of ordinances needed to implement stormwater management criteria.

(13) Provisions for periodically reviewing, revising and updating the plan.

Section 11 discusses the requirement of Section 5(a) of the Act that each plan must be reviewed and any necessary revisions made at least every five years after its initial adoption.

SECTION 5b

(1) Contain such provisions as are reasonably necessary to manage stormwater such that development or activities in each municipality within the watershed do not adversely affect health, safety and property in other municipalities within the watershed and in basins to which the watershed is tributary; and

With the adoption of the Model Stormwater Management Ordinance provided with this Plan, each municipality must enforce development, redevelopment, and other regulated activities consistent with the standards and criteria contained in the Model Ordinance. These standards and criteria have been developed to ensure regulated activities will not adversely affect health, safety, and property in the County.

(2) Consider and be consistent with other existing municipal, county, regional and State environmental and land-use plans.

Section 3 identifies several planning efforts which the County conducted in the past. These include watershed Act 167 Plans, comprehensive planning including open space planning and land use plans, and hazard mitigation planning.

Table 2.1. Elements of Act 167

PLAN ADVISORY COMMITTEES

Public participation by local stakeholders is an integral part of comprehensive stormwater management planning. Coordination amongst these various groups facilitates a more inclusive Plan that is able to better address the variety of issues experienced throughout the county. Several Plan Advisory Committee meetings were held during the development of this Plan.

A Plan Advisory Committee (PAC) was formed at the beginning of the planning process as required by the Stormwater Management Act. The purpose of the PAC is to serve as an access for municipal input, assistance, voicing of concerns and questions, and to serve as a mechanism to ensure that inter-municipal coordination and cooperation is secured. The PAC consists of at least one representative from each of the municipalities within the county, the County Conservation District, and other representatives as appropriate. A full list of the PAC members can be found in the Acknowledgements section at the beginning of this Plan.

As per Act 167, the PAC is responsible for advising the county throughout the planning process, evaluating policy and project alternatives, coordinating the watershed stormwater plans with other municipal plans and programs, and reviewing the Plan prior to adoption. Table 2.2 is a summary of the PAC meetings that were held throughout the planning process.

Meeting	Purpose of Meeting	Meeting Dates
PAC	Phase 2 Start-up Meeting - Introduce the Phase 2 planning process. Emphasize the importance of full municipal involvement. Present a summary of the data collection questionnaire from Phase 1.	September 5, 2008
PAC	Review the project status, maps, institutional data (ordinances, etc), solicit input from municipalities, provide summary of stormwater problems. Identify areas that require detailed hydrologic modeling.	July 8, 2009

Section II – Goals and Objectives of the Act 167 Stormwater Management Plan

MEC	Update MEC on project scope changes due to the PA budget crisis. Present technical details to be included in the Model Ordinance. Solicit input on the technical standards.	October 29, 2009
PAC MEC	Update PAC on progress to date. Present Model Ordinance concepts and standards. Solicit input on specific elements of the ordinance.	December 9, 2009
PAC MEC	General review of the draft Model Ordinance. Gather general comments and feedback prior to finalization of the Model Ordinance. (Draft Model Ordinance sent to municipalities prior to meeting).	February 22, 2010
PAC MEC	General review of draft PLAN. Gather general comments and feedback prior to finalization of the PLAN. (Draft PLAN sent to municipalities prior to meeting).	May 19, 2010
Public Hearing	Conduct the hearing as required by Act 167 to present the PLAN to the public.	June 22, 2010

Table 2.2. Summary of PAC Meetings

GOALS AND OBJECTIVES OF THE PLAN

This plan was developed to present the findings of a two-phased multi-year study of the watersheds in Venango County. Watershed-based planning addresses the full range of hydrologic and hydraulic impacts from cumulative land developments that have taken place in a watershed rather than simply considering and addressing site-specific peak flows. Although this plan represents many things to many people, the principal purposes of the Plan are to protect human health and safety by addressing the impacts of future land use on the current levels of stormwater runoff and to recommend measures to control accelerated runoff to prevent increased flood damages and additional water quality degradation.

The overall objective of this Plan is to provide a framework for comprehensive watershed stormwater management throughout Venango County. The Plan is intended to enable every municipality in the County to meet the intent of Act 167 through the following goals:

1. Manage stormwater runoff created by new development activities by taking into account the cumulative basin-wide stormwater impacts from peak runoff rates and runoff volume.
2. Meet the legal water quality requirements under Federal and State laws.
3. Provide uniform stormwater management standards throughout Venango County.
4. Encourage the management of stormwater to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to protect water resources.
5. Preserve the existing natural drainage ways and water courses.
6. Ensure that existing stormwater problem areas are not exacerbated by future development and provide recommendations for improving existing problem areas.

Section II – Goals and Objectives of the Act 167 Stormwater Management Plan

These goals provided the focus for the entire planning process. A scope of work was developed in Phase 1 that focused efforts on gathering the necessary data and developing strategies that address the goals. With the general focus of the Plan determined, Phase II further researched county-specific information, provided in-depth technical analysis, and developed a model ordinance to achieve these goals. On the following page, *Table 2.3* shows the preferred strategies to address the goals and where these strategies are addressed in the Plan:

1. Manage stormwater runoff created by new development activities by taking into account the cumulative basin-wide stormwater impacts from peak runoff rates and runoff volume	
Develop models of selected watersheds to determine their response to rainfall	<i>Section 6, Appendix C</i>
Determine appropriate stormwater management controls for these basins	<i>Section 7</i>
2. Meet the legal water quality requirements under Federal and State laws	
Provide recommendations for improving impaired waters within the county	<i>Section 9</i>
Encourage the use of particularly effective stormwater management BMPs	<i>Section 7</i>
3. Provide uniform standards throughout Venango County	
Develop a Model Stormwater Management Ordinance with regulations specific to the watersheds within the county	<i>Model Ordinance</i>
Adopt and implement the Model Ordinance in every municipality in Venango County	<i>Model Ordinance</i>
4. Encourage the management of stormwater to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to protect water resources	
Provide education on the correlation between stormwater and other water resources	<i>Section 1, Section 10</i>
Require use of the Design Storm Method or the Simplified Method	<i>Model Ordinance</i>
5. Preserve the existing natural drainage ways and water courses	
Provide education on the function and importance of natural drainage ways	<i>Section 1, Section 10</i>
Protect these features through provisions in the Model Ordinance	<i>Model Ordinance</i>
6. Ensure that existing stormwater problem areas are not exacerbated by future development and provide recommendations for improving existing problem areas	
Develop an inventory of existing stormwater problem areas	<i>Section 5, Appendix B</i>
Analyze problem areas and provide conceptual solutions to the problems	<i>Section 5, Appendix B</i>

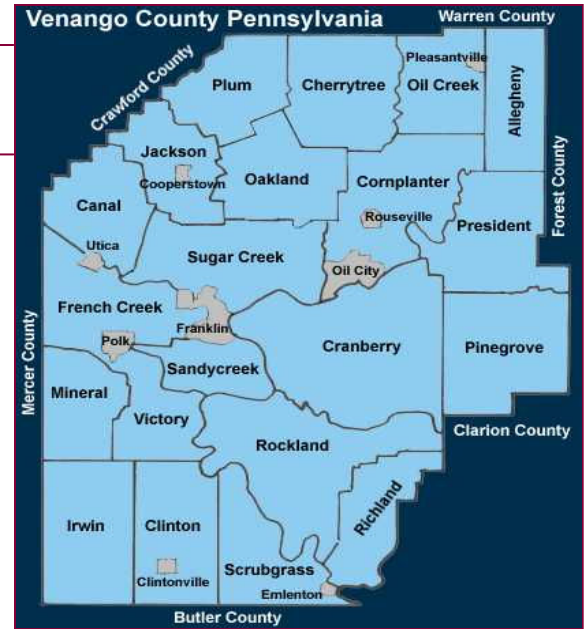
Table 2.3. Preferred Strategies to Address Plan Goals

Section II – Goals and Objectives of the Act 167 Stormwater Management Plan

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Section III – Venango County Description

Venango County was formed on March 12, 1800, from parts of Allegheny and Lycoming Counties. The name originated from the Indian name for French Creek. Venango County is situated on the Allegheny Plateau in the northwestern section of Pennsylvania, about halfway between Erie and Pittsburgh. The County encompasses 432,451 acres (675 square miles) and is approximately 25 miles wide by 29 miles long. The topography of the County is rolling and hilly with approximately 80% of the County being forested terrain. Elevations range from 1,755 feet on a hill near Powell Corners in Pinegrove Township to 860 feet where the Allegheny River flows out of the County at Emlenton. Venango County could best be described as having some characteristics of the industrial northeast and some of rural Appalachia. Parts of the County have been urbanized through industrial growth and its accompanying population growth. However, the bulk of the County has retained its spectacular natural beauty and recreational value.



POLITICAL JURISDICTIONS

The County is comprised of 31 municipalities. The political jurisdictions include nine boroughs, twenty second class townships, and two cities (Oil City and Franklin, the County Seat). Venango County is classified as a sixth class county and is ranked 42nd of 67 counties with a population of 58,359, according to the 2000 census. The 31 municipalities in Venango County and their associated land area are as follows:

TOWNSHIPS	AREA (mi ²)	BOROUGHS	AREA (mi ²)
Allegheny Township	25.0	Sandycreek Township	17.8
Canal Township	24.5	Scrubgrass Township	25.7
Cherrytree Township	36.8	Victory Township	19.9
Clinton Township	28.5	Barkeyville Borough	3.5
Cornplanter Township	37.3	Clintonville Borough	1.1
Cranberry Township	70.4	Cooperstown Borough	0.6
Frenchcreek Township	29.3	Emlenton Borough	0.8
Irwin Township	30.2	Pleasantville Borough	1.0
Jackson Township	24.7	Polk Borough	1.9
Mineral Township	22.5	Rouseville Borough	0.9
Oakland Township	29.0	Sugarcreek Borough	37.4
Oilcreek Township	23.0	Utica Borough	1.3
Pinegrove Township	37.0		
Plum Township	26.6		
President Township	37.4	CITIES	
Richland Township	22.2	Franklin City	4.6
Rockland Township	49.7	Oil City	4.5

Table 3.1. Venango County Municipalities

Section III – Venango County Description

LAND USE

GENERAL DEVELOPMENT PATTERNS

The “core” area of the County which includes both Franklin and Oil City, with portions of Sandycreek and Cranberry Township, has been tentatively identified as a “Designated Growth Area” in the 2005 Venango County Comprehensive Plan. In addition, the PAC has identified the remainder of Cranberry Township, Cornplanter Township, and Sugarcreek Borough as also experiencing developmental growth. These areas have the greatest potential for attracting new development.

Peripheral growth areas include the State Route 8 Corridor south of Franklin and north from Oil City to Rouseville Borough, the interchange area of Clintonville Borough with Interstate 80, the Interstate 80 corridor from Emlenton to Barkeyville, the State Route 27 corridor north from Pleasantville, and segments of the State Route 322 corridor north of Franklin.

TRANSPORTATION

The County is served by two important major transportation routes. Interstate 80, the east-west link from Cleveland to New York, passes through the southern portion of Venango County. Interstate 79, which provides a direct tie from Erie to Pittsburgh, intersects Interstate 80 just a short distance west of Venango County. Other minor transportation routes include United States Highway No. 322 which crosses the County from northwest to southeast and State Route 8 crosses the County from southwest to northeast. Two railroads and one airline also serve the County.

Middle Allegheny River Water Trail, which is an official Pennsylvania Water Trail, measures 85 miles and runs from the Kinzua Dam in Warren County through Venango County to Emlenton.

FARMLANDS

Prime farmland, as defined by the U.S. Department of Agriculture (USDA) in the National Soil Survey Handbook, is the land that is best suited to producing food, feed, forage, and fiber and oilseed crops. It has the soil quality, growing season, and water supply needed to economically produce a sustained high yield of crops when it is treated and managed using acceptable farming methods (NRCS, 2007). In 1972, the USDA assigned the Soil Conservation Service the task of inventorying the prime and unique farmlands and farmlands of state and local importance. This inventory was designed to assist planners and other officials in their decision making to avoid unnecessary, irrevocable conversion of good farmland to other uses. On the USDA's important farmland inventory map, the farmlands are categorized into four classifications: prime farmland, unique farmland, additional farmland of statewide importance, and additional farmland of local importance. According to the USDA, prime farmland soils are usually classified as capability Class I or II. Of Venango County's total land area, 6,487 acres (1.5 percent) are classified as Class I soils and 99,245 acres (22.7 percent) are classified as Class II soils as identified in the *Soil Survey of Venango Counties, Pennsylvania* (SCS, 1975). In addition, 116,994 acres (26.8 percent) are classified as additional farmland of statewide importance.

Farmland soils of statewide importance are soils that are predominantly used for agricultural purposes within a given state, but have some limitations that reduce their productivity or increase the amount of energy and economic resources necessary to obtain productivity levels similar to prime farmland soils. These soils are usually classified as capability Class II or III.

The importance of identifying these areas and planning accordingly is significant. The loss of good farmland is often accompanied by such environmental problems as surface water runoff and interference with the natural recharging of groundwater. Furthermore, when prime agricultural areas are no longer available, farmers will be forced to move to marginal lands,

Section III – Venango County Description

usually on steeper slopes with less fertile soils, which are more apt to erode and less likely to produce. Clearly, decision makers must be able to make informed judgments about the development of farmland. Actions that put high quality agricultural areas into irreversible uses should only be initiated if the actions are carefully considered and are clearly for the benefit of public good.

CLIMATE

Venango County is situated in the Northwest Plateau Climatic Divisions and the climate is classified as humid continental. The area is mostly affected by weather systems that develop in the Central Plains or mid-west and are carried by prevailing westerly winds. Canada is the primary source of cold air and the Gulf of Mexico is the main source of moisture. In general, the winters in Venango County are moderately cold and the summers are warm and somewhat humid. Average highs for the summer linger near 80°F while the maximum temperatures experienced in the summer are usually around 97°F. Cloudiness is prevalent in winter as a result of the “lake effect” of cold air passing over the relatively warm Lake Erie, picking up moisture and resulting in cloud formation. The County’s prevailing January temperature averages near 24°F while the minimum temperatures experienced often dips to anywhere between 10° to 0°F. There are about 130 frost-free days during the year in Venango County. On the average, 140 days of the year will experience some form of precipitation. Annual precipitation is about 40 inches. The average annual snowfall amounts to about 50 inches a year. The first measurable snowfall typically occurs in late November or early December. Most storms result in snowfalls of 10 inches or less. After March, the chance of snow diminishes rapidly.

RAINFALL

Figures 3.1 and 3.2 show the rainfall statistics for Venango County. The average rainfall, shown in Figure 3.1 portrays the amount of precipitation throughout each year since 1900. As shown, there can be significant variation in the annual rainfall total (between 27 and 57 inches). While this variation can have a significant impact on water supply and vegetative growth, it is the quantity of rain in a relatively short time period (1-hour, 6-hour, 24-hour, 48-hour) that receives the focus of most stormwater regulations.

Figure 3.2 shows the annual maximum rainfall events recorded over the same time period graphed and the NOAA Atlas 14 values for the 2-year and 100-year storm events, derived using partial series data. The annual maximum rainfall for a station is constructed by extracting the highest precipitation amount for a particular duration in each successive year of record. A partial duration series is a listing of period of record greatest observed precipitation depths for a given duration at a station, regardless of how many occurred in the same year. Thus, a partial data series accounts for various storms that may occur in a single year.

Historical focus on the annual maximum rainfall and the larger magnitude, low frequency storm events as done in previous stormwater planning efforts throughout Pennsylvania has led to neglect of 1) the majority of storm events that are smaller than the annual maximum and their subsequent value to the landscape in terms of volume and water quality and 2) the fact that inclusion of every storm may increase the 24-hour rainfall total typically used in design.

The majority of rainfall volume in Venango County comes from low magnitude storms. Thus, any stormwater policy should incorporate provisions such as water quality, infiltration, or retention BMPs that account for these small events. It is important to acknowledge that many of these smaller **rainfall** events lead to larger **runoff** events as they may be saturating the soils prior to a larger storm or occurring within a short time period that still overwhelms existing conveyance facilities.

Section III – Venango County Description

Rain gauge information for Franklin is shown in Figures 3.1 and 3.2 (Coop. ID # 363028). Figure 3.2 shows a historic comparison for Venango County rainfall with the NOAA Atlas 14 data. This figure shows that the NOAA Atlas 24-hour, 2-year storm event total of 2.45 inches was exceeded 29 times in more than 110 years of data. When analyzing only the annual maximum series, the NOAA Atlas 24-hour, 2-year storm was exceeded only 24 times. Thus, viewing only the annual maximum series neglects a substantial number of significant historical rainfall events. The implication for stormwater policy in Venango County is that best management practices should incorporate the NOAA Atlas 14, partial duration data series to ensure the best available data is being used for design purposes.

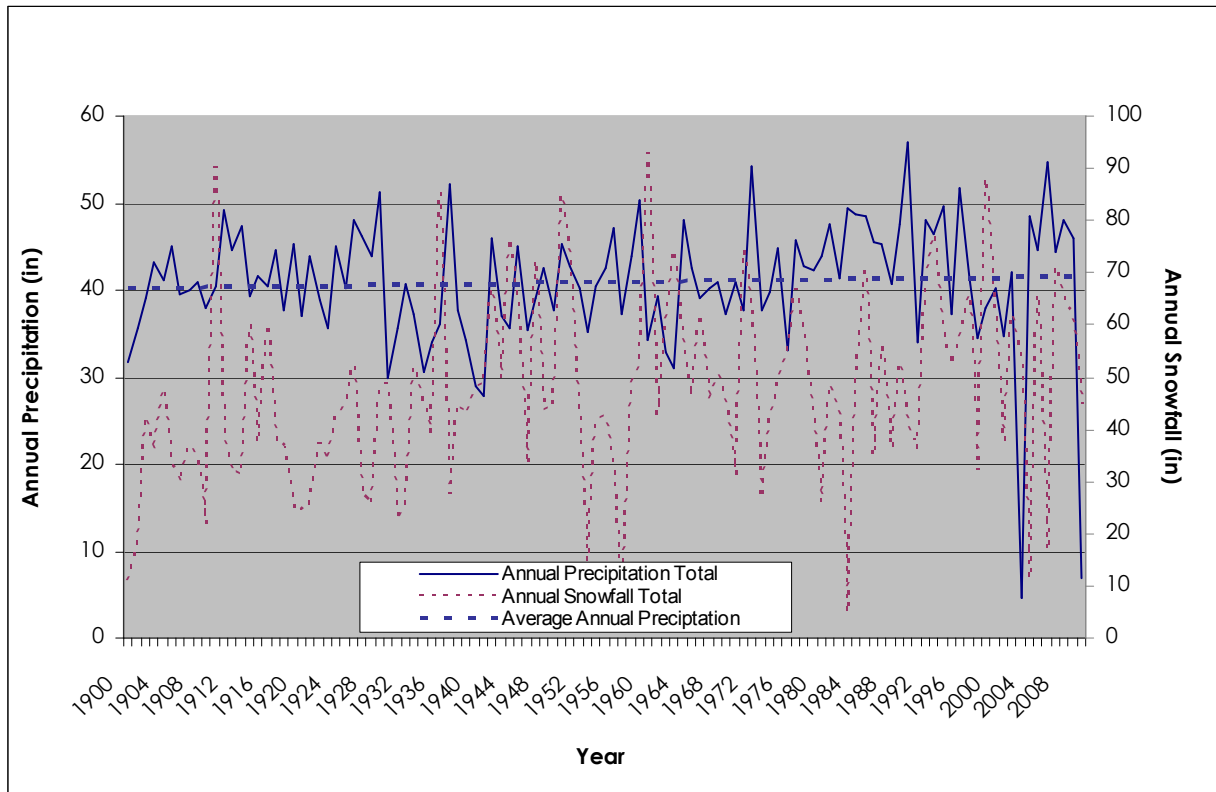


Figure 3.1. Annual Precipitation at Franklin, Pennsylvania (Coop ID #363028)

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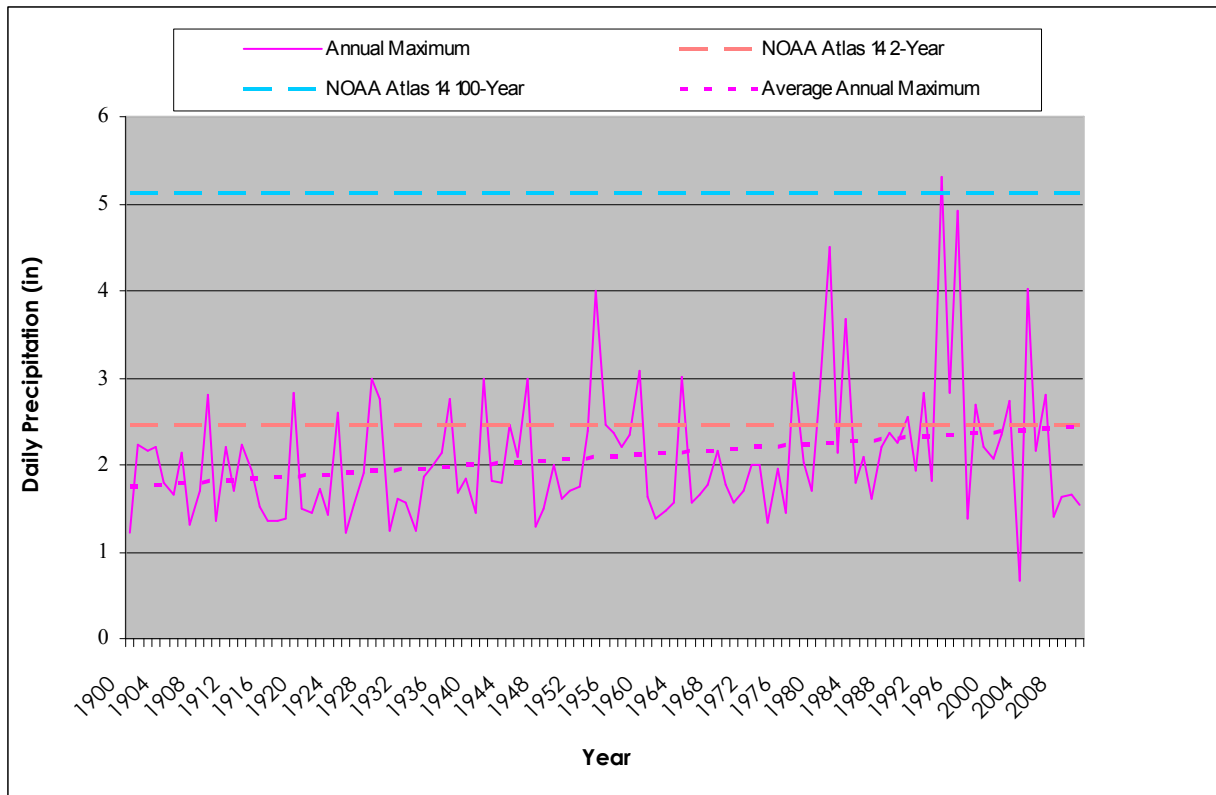


Figure 3.2. Daily Precipitation at Franklin, Pennsylvania (Coop ID #363028)

GEOLOGY

Venango County's present day surface forms were created through several geologic forces acting over many thousands of years. The land emerged from a prehistoric inland sea essentially as a plain comprised of water-deposited materials. Through the action of time and pressure, the earlier deposits of sand, clay, silt, and carboniferous (plant) materials were formed into the sandstone, shale, limestone, and coal strata which make up the bedrock stratigraphy of the area.

In more recent geologic times, several glaciers penetrated into the northwestern part of the County. The glaciers exerted a powerful new force upon the landscape. As they advanced, they penetrated along the stream valleys, filling them with ice and shaping them into the U-shaped cross-sections associated with glacial erosion. As they retreated, they deposited enormous quantities of rock and soil transported from areas to the north. These deposits, in the form of outwash and terminal and ground moraines, modified the underlying land forms. As the glaciers retreated, the removal of the great weight of ice resulted in a gradual uplifting of the entire land mass of the region. At the same time, the down-cutting, eroding forces of the surface streams acted to deepen the ravines and stream valleys. These were the forces, explained here in greatly simplified terms, which produced the form of the land as it now exists in Venango County.

BEDROCK FORMATIONS

Exposed bedrock in Venango County is sedimentary in origin and includes 7 different geologic formations that range from Missipian-Age to Pennsylvania-Age. The formations consist of sandstone, siltstone, shale, and limestone. The formation names are as follows (PA Geological Survey, 2010):

Section III – Venango County Description

Formation	Dominant Lithology
Allegheny Formation	Sandstone
Burgoon Sandstone through Cuyahoga Group, undifferentiated	Sandstone
Corry Sandstone through Riceville Formation, undivided	Sandstone
Cuyahoga Group	Siltstone
Pottsville Formation	Sandstone
Shenango Formation	Sandstone
Shenango Formation through Cuyahoga Group, undivided	Sandstone

Table 3.2. Geologic Formations

In general, the strata of the rocks are nearly level. The lowest lying rocks are the oldest occurring in the central part of the County along the valleys where erosion has cut through the younger Pennsylvanian rocks of the higher elevations. The southern boundary of the County is underlain by the generally flat lying Pennsylvanian Vanport Limestone, a high-calcium limestone. This limestone is generally overlain by less than 100 feet of sedimentary rocks.

The western and northern half of the County was covered in glacial ice. The remnants of the glacial activity are found in gravelly till called moraine, where it is especially noticeable in Canal Township.

OUTSTANDING AND UNIQUE FEATURES

Pennsylvania's outstanding and unique scenic geological features have been identified by the *Outstanding Scenic Geological Features of Pennsylvania* (Geyer and Bolles, 1979). Venango County contains two of these resources as identified below.

Indian God Rock – This feature is located in Rockland Township on the east bank of the Allegheny River, 2 miles north of the village of Brandon, near the 115-mile post on the Penn Central Railroad Tracks. A large outcrop of sandstone (Cuyahoga Group, Mississippian age) forms a sloping, flat bedding surface facing the river. Early Indians carved figures on the face of the rock. The carvings represent their tribes, birds, and animals of the region.

Oil Seeps – Numerous seeps are present in Cherrytree and Oil Creek Townships. They are located along Oil Creek between Oil City and Titusville about 2 miles east of PA Route 8. Oil from these seeps was collected by the Indians and early settlers to be used as medicine. An oil spring was first described in 1753. In 1859 the Drake Well along Oil Creek was the world's first well drilled for oil. A replica of the Drake Well may be seen at Drake Well State Park, Titusville. Large and numerous outcrops of flat-lying greenish-gray siltstones (Riceville Formation, Late Devonian age) are present near Petroleum Center.

SLOPES

The slope of the land is an indication of the developability and use of land. Venango County's land area is comprised of varying degrees of slope, ranging from nearly level plateaus to severe sloping along the rivers of the County. The general characteristics and development potentials and limitations of each category of slope are described as follows:

Section III – Venango County Description

0-8% slope; 265 square miles; 39% of the County. Flat to moderate; capable of all normal development for residential, commercial, and industrial uses; involves minimum amount of earth moving; suited to row crop agriculture, provided that terracing, contour planting, and other conservation practices are followed.

8-16% slope; 152 square miles; 23% of the County. Rolling terrain and moderate slopes; generally suited only for residential development; site planning requires considerable skill; care is required in street layout to avoid long sustained gradients; drainage structures must be properly designed and installed to avoid erosion damage; generally suited to growing of perennial forage crops and pastures with occasional small grain plantings.

16-24% slope; 110 square miles; 16% of the County. Steep slopes; generally unsuited for most urban development; individual residences may be possible on large lot areas, uneconomical to provide improved streets and utilities; overly expensive to provide public services; foundation problems and erosion usually present; agricultural uses should be limited to pastures and tree farms.

24%->slope; 147 square miles; 22% of the County. Severe and precipitous slopes; no development of an intensive nature should be attempted; land not to be cultivated; permanent tree cover should be established & maintained; adaptable to open space uses (recreation, game farms, & watershed protection).

SOILS

The behavior of a soil's response to rainfall and infiltration is a critical input to the hydrologic cycle and in the formation of a coherent stormwater policy. The soils within Venango County have variable drainage characteristics and have various restrictions on their ability to drain, promote vegetative growth, and allow infiltration. They are generally moderately to poorly drained and have a high runoff potential. The following describes the soil series in Venango County (SCS, 1975).

Series Name	Map Symbols	Hydrologic Soil Group	% of County	Restrictions
Allegheny	AgA, AgB	B	0.3	
Alton	AhA, AhB, AhC, AhD, AhF	A	1.2	Lithic bedrock (60-99in.)
Alvira	AlA, AlB, AlC, ArB	C/D	8.9	Fragipan (16-28in.)
Armagh	As	D	0.1	Paralithic bedrock (40-60in.)
Atkins	At	B/D	1.8	Lithic bedrock (60-99in.)
Pits	BP	A	<0.1	
Bethesda	BeB, BeD	C	<0.1	
Brinkerton	BrA, BrB, Bt	C/D	2.5	Fragipan (15-30in.)
Canfield	CdB, CdC, CeB, CeD	C/D	6.7	Fragipan (16-28in.)
Cavode	CIA, ClB, ClC	C/D	5.7	Paralithic bedrock (40-72in.)
Cookport	CoA, CoB, CoC, CpB, CpC	C/D	20.8	Fragipan (20-32in.)
Ernest	ErB	C/D	0.2	Fragipan (20-36in.)
Brinkerton	EsB	D	0.9	Fragipan (15-30in.)
Ernest	EsC	C/D	0.9	Fragipan (20-36in.)
Frenchtown	FeA, FeB	D	1.3	Fragipan (15-32in.)
Pits	GP	D	<0.1	Paralithic bedrock (0-2in.)
Gilpin	GIB, GIC, GID	C	0.9	Lithic bedrock (20-40in.)
Hanover	HaA, HaB, HaC,	C/D	21.2	Fragipan (17-26in.)

Section III – Venango County Description

	HaD, HdB, HdD, HdE			
Hazleton	HeB, HeC, HeD, HIB, HnD, HnF	A	15.3	Lithic bedrock (40-60in.)
Udorthents	ML	C	<0.1	
Monongahela	MoA, MoB	C/D	0.6	Fragipan (25-35in.)
Philo	Ph	B	1.5	
Pope	Po	B	0.9	
Ravenna	RaA, RaB, RaC	D	1.6	Fragipan (14-30in.)
Rexford	Re	D	0.3	Fragipan (18-24in.)
Potomac	Rv	A	<0.1	Lithic bedrock (61-120in.)
Bethesda	Sm	C	1.3	
Tyler	Ty	D	0.2	Fragipan (18-32in.)
Wharton	WhB, WhC	C/D	2.6	Lithic bedrock (40-60in.)
Wooster	WoB, WoC, WoD, WsD, WsE	C	0.7	Fragipan (18-36in.)
Other	W, Um, Qu,	--	1.8	

Table 3.4. Soil Characteristics of Venango County (NRCS, 2008)

One of the impediments to drainage throughout Venango County is the presence of fragipan soils, typically a loamy, brittle soil layer that has minimal porosity and organic content and low or moderate in clay but high in silt or very fine sand. With fragipans, upwards of 60% of input water moves laterally above the fragipan layer which is typically 14-36 inches below the surface in Venango County (Ciolkosz and Waltman, 2000; NRCS, 2008). Thus, higher runoff rates and reduced infiltration capacity typically exist in these soils. Additional impediment to subsurface drainage include lithic and paralithic bedrock (i.e., solid and weather or broken layers of bedrock) although the depths (varying between 2'-10') and type of bedrock (i.e., carbonate bedrock) may offer excellent drainage. Table 3.5 displays the proportion of fragipan and bedrock in Venango County.

Restrictions	% of County
Paralithic bedrock	5.8
Lithic bedrock	21.8
Fragipan	66.8
None defined	5.8

Table 3.5. Soil Restrictions in Venango County

An additional indicator of the response to rainfall of the soils in Venango County is the hydrologic soil group assigned to each soil. This classification varies between "A" which has very low runoff potential and high permeability and "D" which typically has very high runoff potential and low impermeability. Table 3.6 show a summary of the hydrologic soil groups for Venango County. Some soils have variable runoff potential depending on whether or not they are drained or undrained. For example, agricultural field with tile drainage may decrease the runoff potential from hydrologic soil group D to hydrologic soil group A. Over three quarters of the soils in Venango County are hydrologic soil group C or D indicating a high runoff potential (Refer to Plate 4 – Hydrologic Soils).

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Hydrologic Soil Group	Runoff Potential	% of County
A	Low	16.5
B	Low to moderate	2.7
B/D		1.8
C	Moderate to high	2.8
C/D		69.1
D	High	5.2
None Identified	--	1.8

Table 3.6. Hydrologic Soil Groups in Venango County

HYDRIC SOILS

The analysis of hydric soils has recently become an important consideration when performing almost any kind of development review. These soils are important to identify and locate because they provide an approximate location where wet areas may be found. Wetland areas are lands where water resources are the primary controlling environmental factor as reflected in hydrology, vegetation, and soils. Thus, the location of hydric soils is one indication of the potential existence of a wetland area. Wetland areas are now protected by DEP and should be examined before deciding on any type of development activity. According to NRCS, the following table lists the hydric soils found in Venango County:

Alvira silt loam	Cavode silt loam	Pope loam
Armagh silt loam	Cookport loam	Ravenna silt loam
Atkins silt loam	Ernest silt loam	Rexford silt loam
Bethesda very channery silt loam	Frenchtown silt loam	Tyler silt loam
Brinkerton silt loam	Hanover silt loam	Wharton silt loam
Canfield gravelly silt loam	Philo silt loam	

Table 3.7. Hydric Soils

WATERSHEDS

Surface waters include rivers, streams and ponds, which provide aquatic habitat, carry or hold runoff from storms, and provide recreation and scenic opportunities. Surface water resources are a dynamic and important component of the natural environment. However, ever-present threats such as pollution, construction, clear-cutting, mining, and overuse have required the protection of these valuable resources.

Watersheds are delineated and subdivided for the sake of management and analysis. The physical boundaries of a watershed depend on the purpose of the delineation. Often times a watershed is called a "basin" but is also a "subbasin" to an even larger watershed. This indistinct nature often leads to confusion when trying to categorize watersheds. As show in *Figure 3.4*, DEP has divided Pennsylvania into seven different major river basins, based upon the major waterbody to which they are tributary. These include: Lake Erie Basin, Ohio River Basin, Genesee River Basin, Susquehanna River Basin, Potomac River Basin, Elk & Northeast / Gunpowder Rivers Basin, and Delaware River Basin.

Section III – Venango County Description

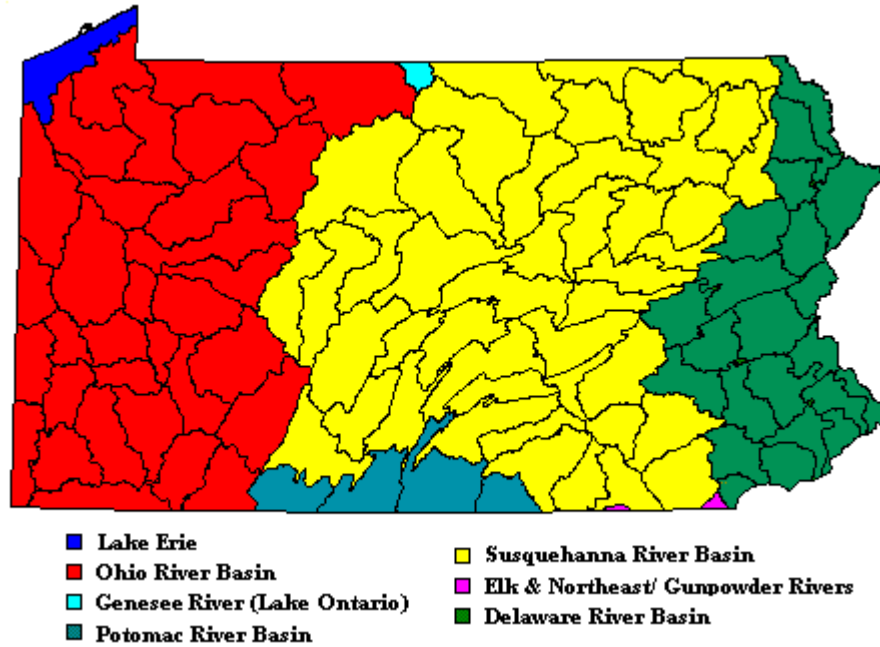


Figure 3.3. Pennsylvania's Major River Basins as Delineated by DEP (DEP, 2009)

For the purpose of this Plan, these are the largest basins in the Commonwealth. The major river basins are further divided into "Act 167 Designated Watersheds" for stormwater management purposes. Act 167 divided the Commonwealth into 29 subbasins and 357 designated watersheds. Venango County lies completely within the Ohio River Basin. Venango County contains at least a portion of eight different Act 167 Designated Watersheds. This classification of the county's watersheds is summarized in the following table:

Major River Basin	Act 167 Designated Watershed
Ohio	Allegheny River
	East Sandy Creek
	French Creek
	Oil Creek
	Sandy Creek
	Slippery Rock Creek
	Sugar Creek
	Wolf Creek

Table 3.8. Classification of Venango County Watersheds

ACT 167 DESIGNATED WATERSHEDS

Three developed municipalities in Venango County are Oil City, Cranberry Township, and Franklin (the county seat). These municipalities are located near the center of Venango County where French Creek and Oil Creek drain into the Allegheny River. As such, a majority of the developed areas of the county is tributary to the Allegheny River. Due to the expectation of future development, all of the subwatersheds that were part of the detailed analysis are located in this central region of the county. The studied subwatersheds are located in portions of the French Creek, Sugar Creek, Sandy Creek, East Sandy Creek, and Allegheny River designated watersheds. The detailed analysis can be found in *Section VI – Technical Analysis – Modeling*. The Act 167 designated watersheds are presented in *Figure 3.4*.

Section III – Venango County Description

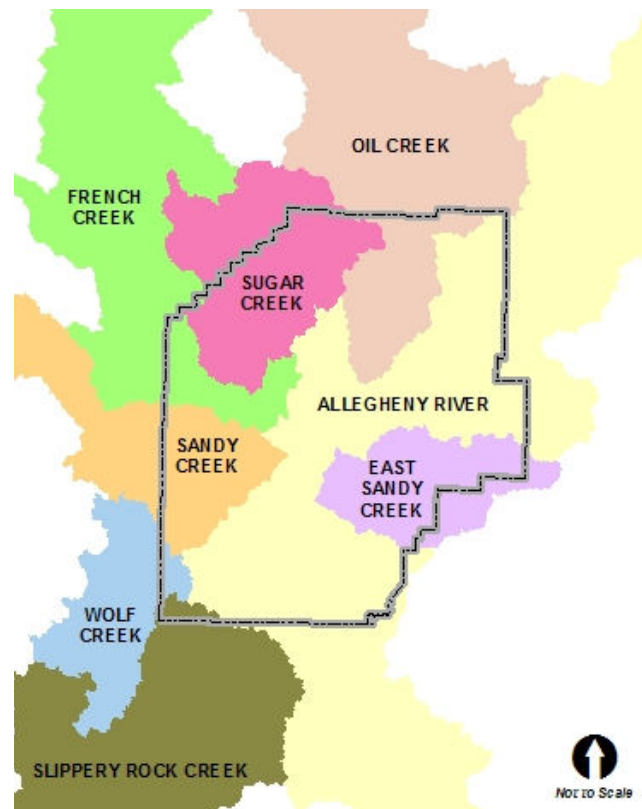


Figure 3.4. Act 167 Watersheds in Venango County

The Borough of Barkeyville, in the southwest corner of the county, has also experienced development due to its location along the Interstate 80 corridor. The developed areas largely drain to the Wolf Creek and Slippery Rock Creek designated watersheds. Their drainage areas cover a small percentage of the county, so they were not studied in detail.

IMPOUNDMENTS

There are no major water impoundments located in Venango County. *Figure 3.5* presents one location in mid Venango County. The Justus Lake location is a minor impoundment which has little to no capacity for flood control.

Section III – Venango County Description

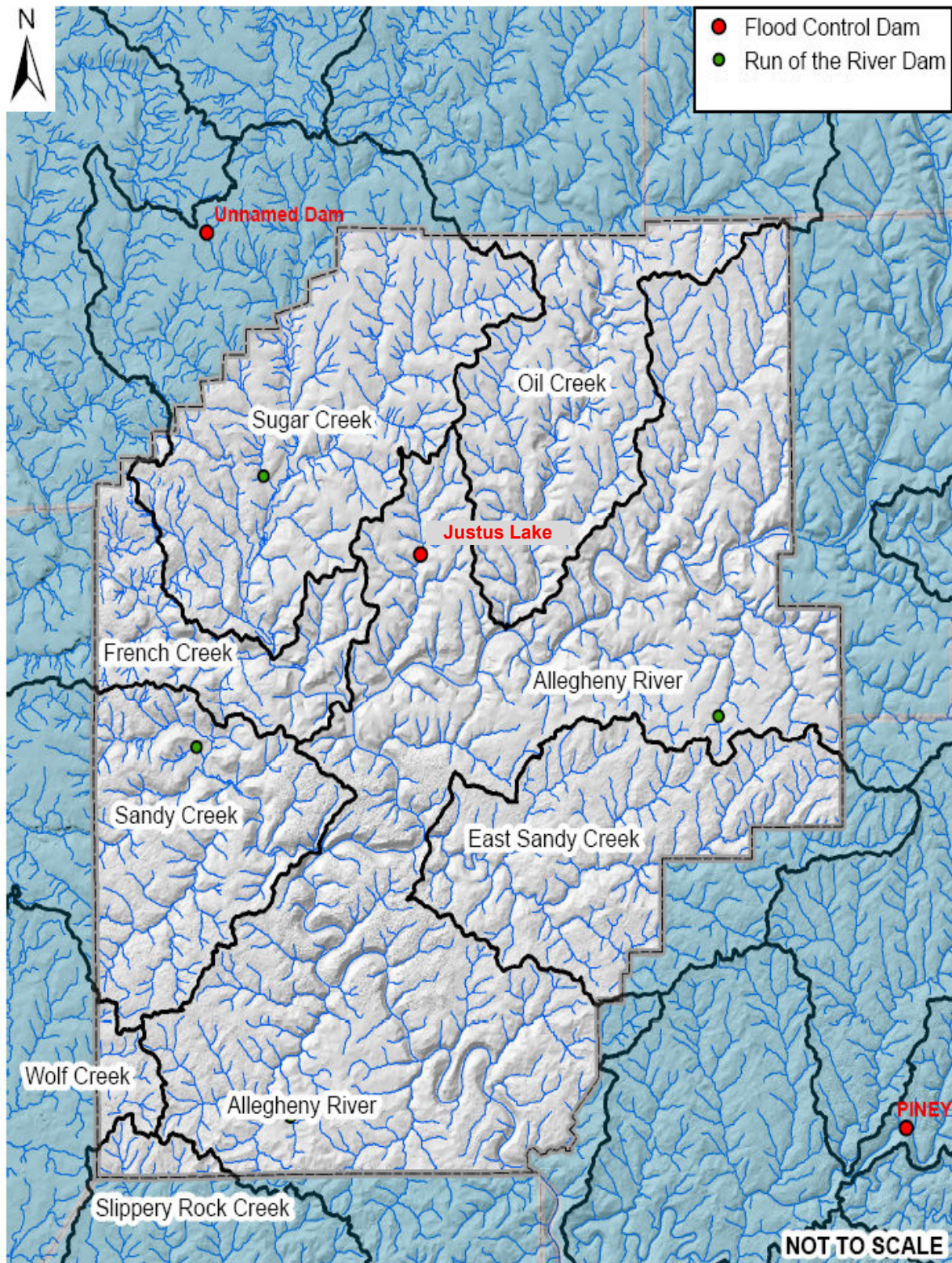


Figure 3.5. Venango County Impoundments

Section III – Venango County Description

SURFACE WATER QUALITY

Water Quality Standards for the Commonwealth are addressed in *The Pennsylvania Code, Title 25, Chapter 93*. Within Chapter 93, all surface waters are classified according to their water quality criteria and protected water uses. According to the antidegradation requirements of §93.4a, "Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." Certain waterbodies which exhibit exceptional water quality and other environmental features, as established in §93.4b, are referred to as "Special Protection Waters." These waters are classified as High Quality or Exceptional Value waters and are among the most valuable surface waters within the Commonwealth. Activities that could adversely affect surface water are more stringently regulated in those watersheds than waters of lower protected use classifications. The existing water quality regulations are discussed in more detail in *Section IV – Existing Stormwater Regulations and Related Plans*.

Venango County streams are shown with their Chapter 93 protected use classification in *Figure 3.5*. (This figure is provided for reference only, the official classification may change and should be checked at: <http://www.pacode.com/index.html>) An explanation of the protected use classifications can be found in *Section IV*.

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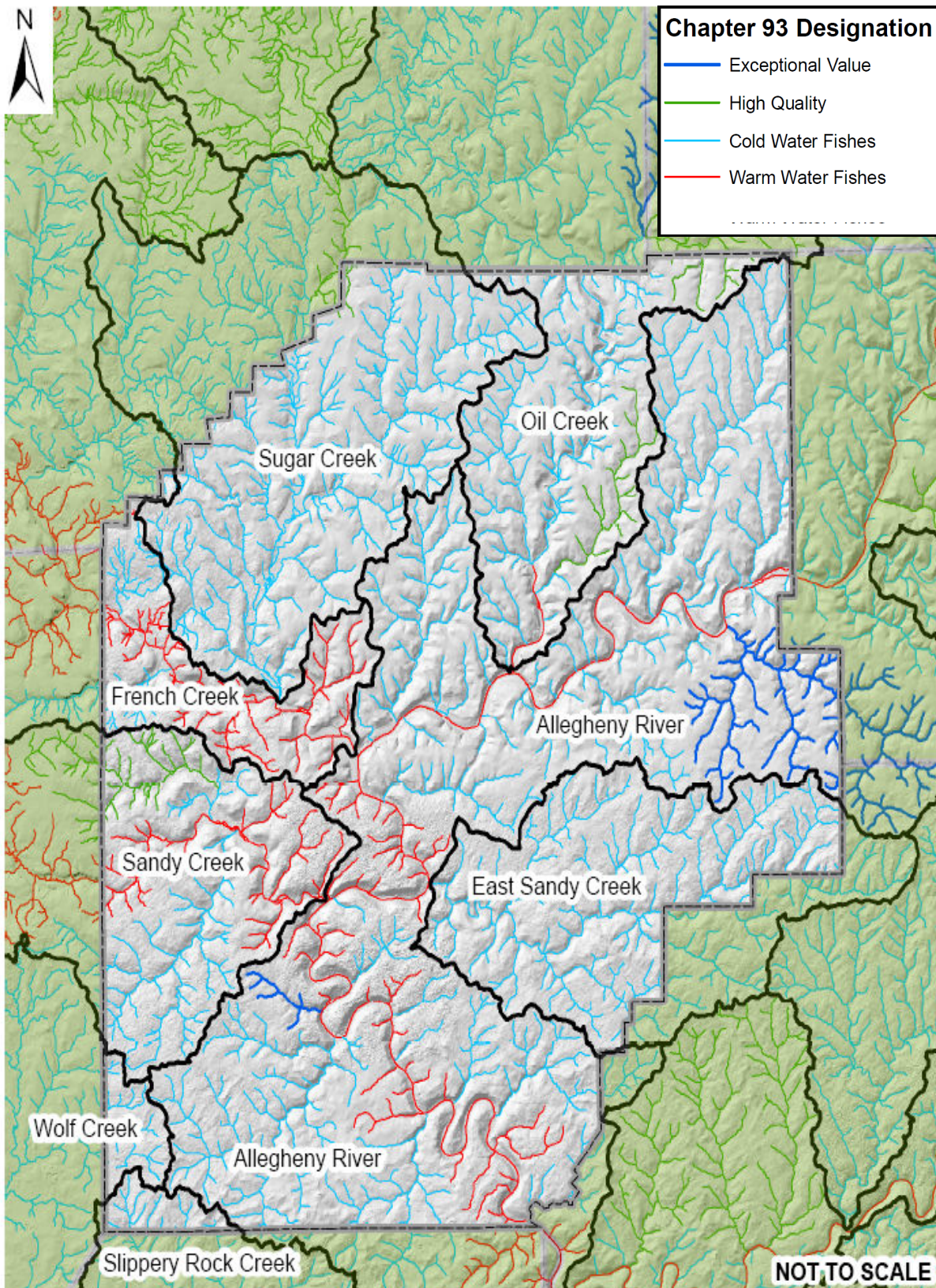


Figure 3.4. Chapter 93 Classification of Venango County Streams

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In Pennsylvania, bodies of water that are not attaining designated and existing uses are classified as “impaired”. Water quality impairments are addressed in *Section IX* of this Plan.

FLOODPLAIN DATA

A flood occurs when the capacity of a stream channel to convey flow within its banks is exceeded and water flows out of the main channel onto and over adjacent land. This adjacent land is known as the floodplain. For convenience in communication and regulation, floods are characterized in terms of return periods, e.g., the 50-year flood event. In regulating floodplains, the standard is the 100-year floodplain, the flood that is defined as having a 1 percent chance of being equaled or exceeded during any given year. These floodplain maps, or Flood Insurance Rate Maps (FIRMs), are provided to the public (<http://msc.fema.gov/>) for floodplain management and insurance purposes.

In 2007, the Pennsylvania Emergency Management Agency (PEMA) completed a statewide study to determine damage estimates for all major flood events. The study computed damages in dollars for total economic loss, building and content damage, and also estimated the number of damaged structures (PEMA, 2009). *Table 3.9* summarizes the findings from this study.

Storm Event	Number of Buildings at Least Moderately Damaged	Total Economic Loss
10	154	\$61 million
50	274	\$97 million
100	360	\$113 million

Table 3.12. Potential Impact Due to Flooding (PEMA, 2009)

Detailed Studies

There are various levels of detail in floodplain mapping. Detailed studies (Zones AE and A1-A30 on the floodmaps) are conducted at locations where FEMA and communities have invested in engineering studies that define the base flood elevation and often distinguish sections of the floodplain between the floodway and flood fringe. See *Figure 3.5* below for a graphical representation of these terms. For a proposed development, most ordinances state that there shall be no increase in flood elevation anywhere within the floodway; the flood fringe is defined so that any development will not cumulatively raise that water surface elevation by more than a designated height (set at a maximum of 1'). Development within the flood fringe is usually allowed but most new construction is required to be designed for flooding (floodproofing, adequate ventilation, etc).

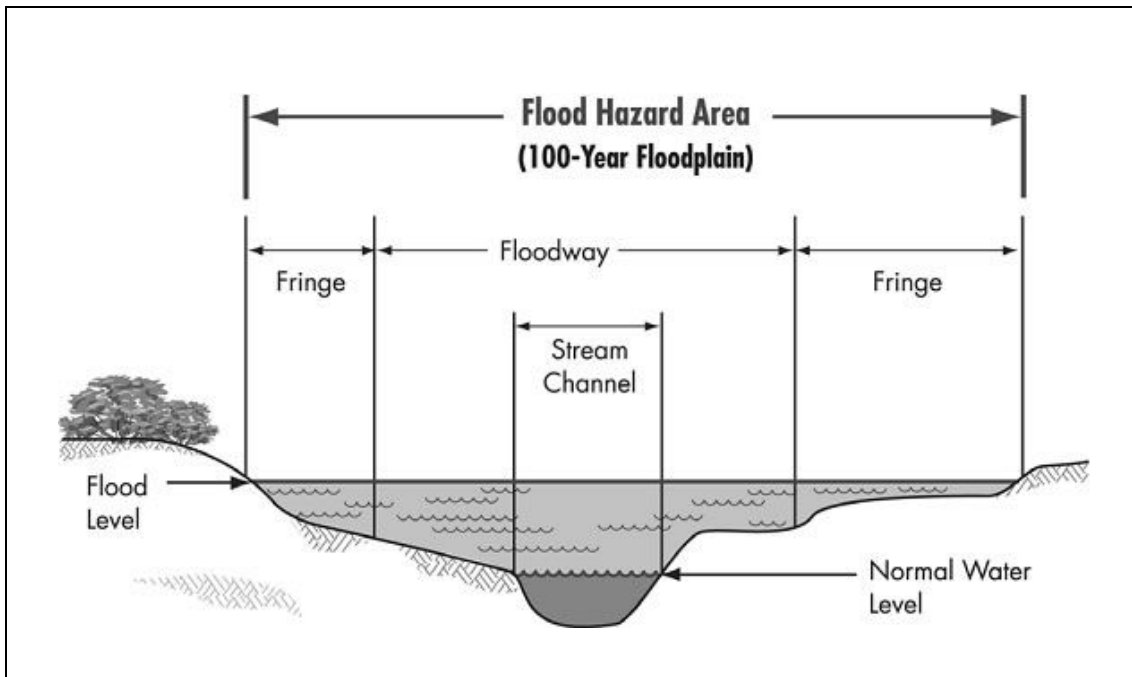


Figure 3.5. Floodplain Cross Section and Flood Fringe (NH Floodplain, 2007)

Approximate Studies and Non-delineated Floodplains

Approximate studies (Zone A on the DFIRM) delineate the flood hazard area, but are prepared using approximate methods that result in the delineation of a floodplain without providing base flood elevations or a distinction between floodway and flood fringe. If no detailed study information is available, some ordinances allow the base flood elevation to be determined based on the location of the proposed development relative to the approximated floodplain; at times, a municipality may find it necessary to have the developer pay for a detailed study at the location in question.

One limitation of FIRMs and older Flood Insurance Rate Maps is the false sense of security provided to home owners or developers who are technically not in the floodplain, but are still within an area that has a potential for flooding. Headwater streams, or smaller tributaries located in undeveloped areas, do not normally have FEMA delineated floodplains. This leaves these areas unregulated at the municipal level, and somewhat susceptible to uncontrolled development. Flood conditions, due to natural phenomenon as well as increased stormwater runoff generated by land development, are not restricted only to main channels and large tributaries. In fact, small streams and tributaries may be more susceptible to flooding from increased stormwater runoff due to their limited channel capacities.

Pennsylvania's Chapter 105 regulations partially address the problem of non-delineated floodplains. Chapter 105 regulations prohibit encroachments and obstructions, including structures, in the regulated floodway without first obtaining a state Water Obstruction and Encroachment permit. The floodway is the portion of the floodplain adjoining the stream required to carry the 100-year flood event with no more than a one (1) foot increase in the 100-year flood level due to encroachment in the floodplain outside of the floodway. Chapter 105 defines the floodway as the area identified as such by a detailed FEMA study or, where no FEMA study exists, as the area from the stream to 50-feet from the top of bank, absent evidence to the contrary. These regulations provide a measure of protection for areas not identified as floodplain by FEMA studies.

Section III – Venango County Description

Levees and other flood control structures

As administrator of the National Flood Insurance Program (NFIP), FEMA has a series of policies and guidelines concerning the protection of life and property behind levees. Periodically, FEMA updates the effective FIRMs as new hydrologic and hydraulic data become available and to reflect changes within the community. In the ongoing map update process, FEMA issued Procedure Memorandum 43 (PM 43) – Guidelines for Identifying Provisionally Accredited Levees (PALs) (FEMA, 2007). For communities with levees, PM 43 has potential to substantially impact the communities protected by levees. A PAL is a levee that has previously been accredited with providing 1-percent-annual-chance flood protection on an effective FIRM. After being designated as a PAL, levee owners will have up to 24 months to obtain and submit documentation that the levee will provide adequate protection against a 1-percent-annual-chance flood. If the levee cannot be certified as providing protection from the 1-percent-annual-chance flood, the areas currently being protected by the levees will be mapped and managed as if they were within the floodplain (i.e., in most cases, the residents and businesses currently being protected by the levees would be forced to purchase flood insurance in accordance with the NFIP).

There is one levee project in Venango County:

Project (Year Constructed)	Owner	Waterbody	PAL Levee Status
Oil City (1958)	Oil City	Oil Creek	Pre-PAL

Table 3.10. Levee Systems in Venango County

Community Rating System (CRS)

To reduce flood risk beyond what is accomplished through the minimum federal standards, the NFIP employs the Community Rating System to give a credit to communities that reduce their community's risk through prudent floodplain management measures. Several of these measures coincide with the goals and objectives of this plan: regulation of stormwater management, preservation of open space, and community outreach for the reduction of flood-related damages.

Flood insurance premiums can be reduced by as much as 45% for communities that obtain the highest rating. Only 28 of the Commonwealth's 2500+ municipalities participate in the CRS. Currently, there are no municipalities in Venango County participating in the CRS.

FIRM Updates

As new information becomes available, FEMA periodically updates the FIRMs to reflect the best available data and to address any new problem areas. Venango County is scheduled to have a preliminary FIRM update available by December 2010. This will correspond to an effort by DCED to have all municipalities adopt and implement a new floodplain model ordinance that conforms to federal and state requirements.

Section III – Venango County Description

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Section IV – Existing Stormwater Regulations and Related Plans

It is often helpful to assess the current regulations when undertaking a comprehensive planning effort. An understanding of current and past regulations, what has worked in the past, and what has failed, is a key component of developing a sound plan for the future. Regulations affecting stormwater management exist at the federal, state, and local level. At the federal level the regulations are generally broad in scope, and aimed at protecting health and human welfare, protecting existing water resources and improving impaired waters. Regulations generally become more specific as their jurisdiction becomes smaller. This system enables specific regulations to be developed which are consistent with national policy, yet meet the needs of the local community.



EXISTING FEDERAL REGULATIONS

Existing federal regulations affecting stormwater management are very broad in scope and provide a national framework within which all other stormwater management regulations are developed. An overview of these regulations is provided below in *Table 4.1*.

Clean Water Act	Section 303	Requires states to establish Total Maximum Daily Loads for point sources of pollution that are allowable to maintain water quality and protect stream flora and fauna. Other water quality standards (e.g., thermal) are also regulated.
Clean Water Act	Section 404	Regulates permitting of discharge of dredged or fill material into the waters of the United States. Includes regulation of discharge of material into lakes, navigable streams and rivers, and wetlands.
Clean Water Act	Section 401/402	Authorizes the Commonwealth to grant, deny, or condition Water Quality Certification for any licensed activity that may result in a discharge into navigable waters. Established the National Pollutant Discharge Elimination System (NPDES) that regulates any earth disturbance activity of 5 acres (or more) or 1 acre (or more) with a point source discharge.
Rivers and Harbors Act of 1899	Section 10	Regulates activities that obstruct or alter any navigable waters of the United States.
Federal Emergency Management Act		Requires that any proposed structure within the floodplain boundaries of a stream cannot cause a significant increase in the 100-year flood height of the stream.

Table 4.1. Existing Federal Regulations

Section IV – Existing Stormwater Regulations and Related Plans

EXISTING STATE REGULATIONS

Pennsylvania has developed stormwater regulations that meet the federal standards and provide a statewide system for stormwater regulation. State regulations are much more specific than federal regulations. Statewide standards include design criteria and state issued permits. State regulations cover a variety of stormwater related topics. A brief review of the existing state regulations is provided below in *Table 4.2*.

Chapter 92	Discharge Elimination	Regulates permitting of point source discharges of pollution under the National Pollutant Discharge Elimination System (NPDES). Storm runoff discharges at a point source draining five (5) or more acres of land or one (1) or more acres with a point source discharge are regulated under this provision.
Chapter 93	Water Quality Implementation Standards	Establishes the Water Use Protection classification (i.e., water quality standards) for all streams in the state. Stipulates anti-degradation criteria for all streams.
Chapter 96	Water Quality Implementation Standards	Establishes the process for achieving and maintaining water quality standards applicable to point source discharges of pollutants. Authorizes DEP to establish Total Mass Daily Loads (TMDLs) and Water Quality Based Effluent Limitations (WQBELs) for all point source discharges to waters of the Commonwealth.
Chapter 102	Erosion and Sediment Control	Requires persons proposing or conducting earth disturbance activities to develop, implement and maintain Best Management Practices to minimize the potential for accelerated erosion and sedimentation. Current DEP policy requires preparation and implementation of a post-construction stormwater management (PCSM) plan for development areas of 5 acres or more or for areas of 1 acre or more with a point source discharge.
Chapter 105	Dam Safety and Waterway Management	Regulates the construction, operation, and maintenance of dams on streams in the Commonwealth. Also regulates water obstructions and encroachments (e.g., road crossings, walls, etc.) that are located in, along, across or projecting into a watercourse, floodway, wetland, or body of water.
Chapter 106	Floodplain Management	Manages the construction, operation, and maintenance of structures located within the floodplain of a stream if owned by the State, a political subdivision, or a public utility.

Table 4.2. Existing State Regulations

STATE WATER QUALITY STANDARDS

Water Quality Standards for the Commonwealth are addressed in *The Pennsylvania Code, Title 25, Chapter 93*. Within Chapter 93, all surface waters are classified according to their water

Section IV – Existing Stormwater Regulations and Related Plans

quality criteria and protected water uses. The following is an abbreviated explanation of these standards and their respective implications to this Act 167 plan.

General Provisions (§93.1 - §93.4)

The general provisions of Chapter 93 provide definitions, citation of legislative authority (scope), and the definition of protected and statewide water uses. DEP's implementation of Chapter 93 is authorized by the Clean Streams Law, originally passed in 1937 to "preserve and improve the purity of the waters of the Commonwealth for the protection of public health, animal and aquatic life, and for industrial consumption, and recreation," and subsequently amended. *Table 4.3* is a summary of the protected water uses under Chapter 93 that are applicable to Venango County.

Protected Use	Relative Level of Protection	Description
Aquatic Life		
Warm Water Fishes (WWF)	Lowest	Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Trout Socking (TSF)		Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Cold Water Fishes (CWF)		Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.
Special Protection		
High Quality Waters (HQ)		A surface water that meets at least one of chemical or biological criteria defined in §93.4b
Exceptional Value Waters (EV)	Highest	A surface water that meets at least one of chemical or biological criteria defined in §93.4b <u>and</u> additional criteria defined in §93.4b.(b)

Table 4.3. Chapter 93 Designations in Venango County

Antidegradation Requirements (§93.4a - §93.4d)

According to the antidegradation requirements of §93.4a, "Existing in-stream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." Certain waterbodies which exhibit exceptional water quality and other environmental features, as established in §93.4b and summarized in *Table 4.3*, are referred to as "Special Protection Waters." Activities that could adversely affect surface water are more stringently regulated in those watersheds than waters of lower protected use classifications. For WWF, TSF, or CWF waterbodies, many of the antidegradation requirements can be

Section IV – Existing Stormwater Regulations and Related Plans

addressed using guidance provided in this plan and the DEP BMP Manual; for HQ or EV watersheds, the current regulations follow DEP's antidegradation policy.

For a new, or additional, point discharge with a peak flow increase to an HQ or EV water, the developer is required to use a non-discharge alternative that is cost-effective and environmentally sound compared with the costs of the proposed discharge. If a non-discharge alternative is not cost-effective and environmentally sound, the developer must use the best available combination of treatment, pollution prevention, and wastewater reuse technologies and assure that any discharge is non-degrading. In the case where allowing lower water quality discharge is necessary to accommodate important economic or social development in an area, DEP may approve a degrading discharge after satisfying a multitude of intergovernmental coordination and public participation requirements (DEP, 2003).

Water Quality Criteria (§93.6 - §93.8c)

In general, the water discharged from either a point source or a nonpoint source discharge may contain substances in a concentration that would be inimical or harmful to a protected water use. The specific limits for toxic substances, metals, and other chemicals are listed in this section.

Designated Water Uses and Water Quality Criteria (§93.9)

The designated use and water quality criteria for each stream reach or watershed is specified. Below and on the following page, *Table 4.4* shows the Chapter 93 designated uses for Venango County as defined by §93.9 and *Table 4.5* summarizes the uses by watershed. A majority of the watersheds in Venango County have been designated as cold water fisheries.

Drainage List Q – Ohio River Basin in Pennsylvania - Allegheny River	
Richey Run	CWF
UNT to Oil Creek	CWF
UNT to Allegheny River	CWF
Holeman Run	CWF
Stewart Run	CWF
Fox Run	CWF
Johnston Run	CWF
McCrea Run	CWF
Culver Run	CWF
Muskrat Run	CWF
Pithole Creek	CWF
Panther Run	CWF
Lamb Run	CWF
Horse Creek	CWF
Carney Run	CWF
Sage Run	CWF
Oil Creek	CWF
Benninghof Run	CWF
Cherrytree Run	CWF
UNT to Oil Creek	CWF
Cherry Run	CWF
Cornplanter Run	CWF
Holiday Run	CWF
Charley Run	CWF
Brannon Run	CWF

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Seneca Run	CWF
Twomile Run	CWF
McCune Run	CWF
Mill Creek	CWF
Sugar Creek	CWF
Lower Twomile Run	CWF
East Sandy Creek	CWF
Snyder Run	CWF
Unnamed Tributary to Little Sandy Creek at RM 1.16	CWF
Little Sandy Creek	CWF
South Sandy Creek	CWF
Pine Hill Run	CWF
Scrubgrass Creek	CWF
Unnamed Tributary to Allegheny River at RM 106.70	CWF
Roberts Run	CWF
Whitherup Run	CWF
Little Scrubgrass Creek	CWF
Shull Run	CWF
Mill Creek	CWF
Cherry Run	HQ-CWF
Little Sandy Creek	HQ-CWF
Hemlock Creek	EV
Dennison Run	EV
UNT to Sandy Creek	WWF
UNT to French Creek	WWF
Oil Creek	WWF
French Creek	WWF
Patchel Run	WWF
UNT to Allegheny River	WWF
Siefer Run	WWF
Ajax Run	WWF
Sandy Creek	WWF
Sulphur Run	WWF
Morrison Run	WWF
Victory Run	WWF
Ditzenberger Run	WWF
Clark Run	WWF
Falling Spring Run	WWF
Perry Run	WWF
Whann Run	WWF
UNT to Allegheny River	WWF

Table 4.4. Venango County Designated Water Uses

Section IV – Existing Stormwater Regulations and Related Plans

Classification	Category	Allegheny River	East Sandy Creek	French Creek	Oil Creek	Sandy Creek	Slippery Rock Creek	Sugar Creek	Wolf Creek	Entire County	Percent of County
Chapter 93 (miles)	EV	68.6	--	--	--	--	--	--	--	68.6	4.1
	HQ-CWF	--	--	--	29.9	28.9	--	5.1	--	64.0	3.8
	HQ-TSF	--	--	--	--	--	--	--	--	0.0	0.0
	HQ-WWF	--	--	--	--	--	--	--	--	0.0	0.0
	CWF	502.4	170.2	45.2	131.8	68.6	19.8	293.2	19.2	1250.3	74.2
	TSF	--	--	--	--	--	--	--	--	0.0	0.0
	WWF	149.2	--	77.8	9.2	66.3	--	--	--	302.5	17.9
	Total	720.2	170.2	122.9	170.9	163.8	19.8	298.3	19.2	1685.3	100.0

Table 4.5. Venango County Summary of Designated Water Uses by Watershed

Water Quality Impairments and Recommendations

In addition to the Chapter 93 regulations, DEP has an ongoing program to assess the qualities of water in Pennsylvania and identify streams and other bodies of water that are not attaining the required water quality standards. These “impaired” streams, their respective designations, and the subsequent recommendations are discussed in *Section IX*.

EXISTING MUNICIPAL REGULATIONS

In Pennsylvania, stormwater management regulations usually exist at the municipal level. A review of the existing municipal regulations helps us unravel the complex system of local regulation and develop watershed wide policy that both fits local needs and provides regional benefits. *Table 4.6* provides a summary of existing regulations for the 31 municipalities within Venango County.

VENANGO COUNTY MUNICIPAL ORDINANCES

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT (SALDO)	ZONING	FLOODPLAIN MANAGEMENT
Allegheny Township	No	No (County)	No	Yes Ord 1-80 & 3-85
Barkeyville Borough	No	No (County)	Yes 1999	Yes Zoning
Canal Township	No	No (County)	No	Yes *
Cherrytree Township	No	No (County)	Yes 2006	Yes *
Clinton Township	No	No (County)	No	Yes *
Clintonville Borough	No	No (County)	No	Yes *
Cooperstown Borough	No	No (County)	No	Yes *
Cornplanter Township	No	No (County)	Yes 1994	Yes Ord 42 of 1987
Cranberry Township	No	No (County)	Yes 1995	Yes Separate Ord
Emlenton Borough	No	No (County)	Yes No. 195	Yes *
City of Franklin	No	Yes On Internet	Yes 1995 2005	Yes Zoning
Frenchcreek Township	No	No (County)	No	Yes Ord 2 of 1982 Ord 2-1 of 1987

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MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT (SALDO)	ZONING	FLOODPLAIN MANAGEMENT
Irwin Township	No	No (County)	No	Yes *
Jackson Township	No	No (County)	No	Yes *
Mineral Township	No	No (County)	No	Yes *
Oakland Township	No	No (County)	No	Yes *
City of Oil City	No	No (County)	Yes	Yes *
Oil Creek Township	No	No (County)	No	Yes *
Pinegrove Township	No	No (County)	No	Yes *
Pleasantville Borough	No	No (County)	Yes 1994	Yes *
Plum Township	No	No (County)	No	Yes *
Polk Borough	No	No (County)	No	Yes *
President Township	No	No (County)	No	Yes *
Richland Township	No	No (County)	No	Yes *
Rockland Township	No	No (County)	No	Yes *
Rouseville Borough	No	No (County)	Yes 1997	Yes Ord 198 of 1988
Sandycreek Township	Yes 2004	Yes 2006	Yes 2009	Yes Ord 1 of 1989 Ord 3 of 1990
Scrubgrass Township	No	No (County)	No	Yes *
Sugarcreek Borough	No	No (County)	Yes 1986	Yes Zoning
Utica Borough	No	No (County)	No	Yes *
Victory Township	No	No (County)	No	Yes *

Table 4.6. Venango County Municipal Ordinance Matrix

Table 4.7 shown on the following pages is a brief summary of the results of an ordinance review of the existing municipal regulations and the stormwater management provisions contained within each Ordinance.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
County of Venango	Partially covered in SALDO	Adopted October 5 th 2005	There is no county wide zoning ordinance	Covered in the SALDO section 402
Allegheny Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Ordinance No. 1-80 and 3-85
Barkeyville Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance Effective May 13 th 1999 (currently updating)	Covered under section 611.1 and 611.2 of Zoning Ordinance
Canal Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Cherrytree Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance Effective May 1 st , 2006	Mentioned in Oil Creek Regional Comp Plan

Section IV – Existing Stormwater Regulations and Related Plans

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Clinton Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Clintonville Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Cooperstown Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Cornplanter Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance Effective 1994	Ordinance No. 42 Effective April 11 th 1987
Cranberry Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance Effective 1995	Has a Floodplain Management Ordinance
Emlenton Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance No. 195	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
City of Franklin	Covered within City's Codified Ordinances	Has own Subdivision Code	Has Zoning Ordinance No. 7 of 1995 November 6 th 2005	Article 1309 of City's Zoning Ordinance
Frenchcreek Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Ordinance 2 of 1982 & Ordinance 2-01 of 1987
Irwin Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Jackson Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)

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MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Mineral Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Oakland Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
City of Oil City	Covered under Zoning	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning	Has Floodplain Ordinance
Oil Creek Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Pinegrove Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Pleasantville Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance No. 242 of 1994	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Plum Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Polk Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
President Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Richland Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)

Section IV – Existing Stormwater Regulations and Related Plans

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Rockland Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Rouseville Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance No. 217 11/11/1997	Ordinance No. 195 1988
Sandycreek Township	Ordinance No. 4 of 2004	Has a SALDO effective 2006	Has Zoning Ordinance Effective July 2009	Ordinance No. 1 of 1989 and also No 3. of 1990
Scrubgrass Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Sugarcreek Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	Has Zoning Ordinance Effective November 5 th , 1986	Covered in sections 414.1 and 414.2 of Zoning Ordinance
Utica Borough	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)
Victory Township	No Ordinance	Falls under the jurisdiction of Venango County Subdivision and Land Ordinance	No Ordinance	Believed to have adopted Single Purpose Flood Management Ordinance section 1910.3(b)

Table 4.7. Municipal Ordinance Review

EXISTING RELATED PLANS

Review of previous planning efforts is another important component of regional planning. An analysis of previous plans, and the results achieved through implementation of recommendations within those plans, provides invaluable information for current and future planning efforts. The following table is a summary of related plans which includes a listing of pertinent plan goals:

PLAN TITLE	DATE	AUTHOR	PERTINENT PLAN GOALS
Venango County Comprehensive Plan	2004	Venango County Regional Planning	
Venango County Greenways	2009	Pashek Associates	

Table 4.8. Related Plans Review

Section V – Significant Problem Areas and Obstructions

One of the stated goals of this Plan is to “ensure that existing stormwater problem areas are not exacerbated by future development and provide recommendations for improving existing problem areas.” The strategy for achieving this goal required identification of the existing significant stormwater problem areas and obstructions, and then evaluation of the identified problem areas and obstructions.



The first task was to identify the location and nature of existing drainage problems within the study area, and where appropriate, gather field data to be used for further analysis of the problem. The geographical location data was used to plot all of the problem areas and obstructions on a single map (Reference Plate 9 – Problem Areas & Obstructions). Mapping the location of the sites in this manner enables you to identify isolated problems and determine which problems are a part of more systemic problems. Systemic problems are often an indication that larger stormwater management problems exist, which may warrant more restrictive stormwater regulations. This information was used when modeling the watersheds and determining appropriate stormwater management controls.

The second part of this task was to analyze individual problem areas and obstructions, determine potential solutions for the most significant problems, and provide recommendations that can be implemented through the Venango County Stormwater Management Plan. All of the problem areas and obstructions were evaluated and potential solutions were developed. Where possible, the individual problem areas and obstructions were modeled to determine approximate capacities to be used for planning purposes. Then a preliminary prioritization assessment was conducted to give a County-wide overview of the severity of the existing problems. The priority assessment also provides general guidance on the relative order in which the problems should be addressed when considered at a County-wide level.

IDENTIFICATION OF PROBLEM AREAS AND OBSTRUCTIONS

Identification and review of existing information concerning the County's stormwater systems, streams, and tributary drainage basins within the project limits was conducted during Phase I and Phase II of this Plan. During Phase I, questionnaires were distributed to all of the municipalities in Venango County. The questionnaire enabled the municipalities to report all of the known problem areas and obstructions within their municipality. Of the 31 municipalities in Venango County, 20 participated in the assessment process by returning completed questionnaires. The responses were summarized and reported in the Phase I report of this Plan. The responses were reviewed during Phase II of the Act 167 planning process. Field reconnaissance was subsequently conducted to confirm problem area locations, assess existing conditions, identify the general drainage patterns and gather data to complete a planning level analysis.

All of the reported problem areas and obstructions are listed in *Tables 5.1 and 5.2*, respectively on the following pages. A more detailed explanation of each site can be found in *Appendix C – Significant Problem Area Modeling and Recommendations*, which contains a summary of all of the data collected for each of the problem areas and obstructions reported throughout the County.

Section V – Existing Stormwater Regulations and Related Plans

ID	MUNICIPALITY	LOCATION	DESCRIPTION
P1	Barkeyville Bor	Route 8, South of Route 208	Blocked Culvert
P2	Barkeyville Bor	Cockain Road Culverts	Siltation of Roadside swales
P3	City of Franklin	Chub Run between 14th & 15th	Undersized Culverts
P3	City of Franklin	Spring Street	Undersized Storm Sewers
P5	City of Oil City	Sage Run	
P6	City of Oil City	Union St./Cornplanter Run	
P7	City of Oil City	Colbert Ave Streams	
P8	City of Oil City	Hasson Park	
P9	City of Oil City	Cooper Run	
P10	City of Oil City	Willow/Alcorn	
P13	City of Oil City	Oliver Manor	
P14	City of Oil City	Marina	
P15	City of Oil City	Spring Street	Springs
P16	City of Oil City	Colbert Ave	Springs
P17	City of Oil City	Moran Street	Springs
P18	City of Oil City	Plummer Street	Springs
P19	City of Oil City	E. Eight Street	Springs
P20	City of Oil City	Mylan Street	Springs
P21	City of Oil City	Harold Street	Springs
P22	City of Oil City	Summit Street	Springs
P23	City of Oil City	Halyday Street	Springs
P24	City of Oil City	Dwyer Street	Springs
P25	City of Oil City	Spruce Street	Springs
P27	VCCD	Cranberry Mall	Stormwater Pond
P28	VCCD	Wal-Mart	Stormwater Pond
P29	Cornplanter Twp	Scott Drive	Storm Sewers
P30	Cornplanter Twp	Russell Corner Rd - Oil Creek	Drainage
P31	Cranberry Twp	Lower Two Mile Run	Channel Dredging & Cleaning
P32	Cranberry Twp	Sage Run	Widening Channel
P33	Cranberry Twp	Halls Run	Channel Cleaning
P34	Cranberry Twp	Horse Creek	Sediment Removal
P35	Cranberry Twp	Sandy Creek	Widening Channel
P36	Frenchcreek Twp	French Creek Rd T- 356	Steep Bank - Erosion
P37	Frenchcreek Twp	Mapledale	Localized Flooding
P39	Jackson Twp	Sugar Creek near Tologa Rd.	Bank Erosion
P40	Jackson Twp	Wolf Run on Rodger Road	Bank Erosion
P41	Mineral Twp		Water Wash Out
P42	Mineral Twp		Flat Area
P43	Mineral Twp		Hill Washing Out
P44	Oakland Twp	Davis Road	
P45	Oakland Twp	Race Track	
P46	Oakland Twp	Prather Run/East Branch Sugarcreek	
P47	Plum Twp	McKinsey Road	Streambank Erosion
P48	Plum Twp	Knightlanger Road	Flooding
P49	Plum Twp	Acel Road	
P50	Plum Twp	Knepp Hill Road	Flooding
P51	Rouseville Bor	Hiland Ave.	Bank - Hillside Runoff
P52	Rouseville Bor	Bankson Rd	Ditches Washing Fill In Pipes
P53	Sandycreek Twp	Morrison Run at Nightingale W of Rt 8	Increase Unmanaged Runoff
P54	Sandycreek Twp	Chubb Run - Martino's to Franklin City	Increase Unmanaged Runoff
P59	Sugarcreek Bor	Route 417 High School South	
P60	Sugarcreek Bor	Route 322 at Wyattville	

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ID	MUNICIPALITY	LOCATION	DESCRIPTION
P61	Sugarceek Bor	Sugar Creek @ Orr's to Weaver Street	
P63	Sugarceek Bor	McCleary Road @ Bridge	
P64	Sugarceek Bor	Route 8 Health	
P65	Sugarceek Bor	Shafer Run 1 mile Upstream	
P66	Sugarceek Bor	Keely Road near Titus	
P67	Utica Bor	French Creek Flooding	Flooding
P68	Utica Bor	Mill Creek Stream	Erosion
P69	Utica Bor	Mill Creek Flooding	Flooding
P70	Utica Bor	Loosing Mill Creek Bridge	Erosion
P71	City of Franklin	Chubb Run T.R. 8	Steep Stream Bed - Eroding Gabions & Bank
P72	City of Franklin	700 and 800 Blocks of Buffalo St.	Increased runoff from development
P73	City of Franklin	700 Block of Buffalo St.	Increased runoff from development - water line
P74	City of Franklin	803 Buffalo St.	Flooding of Basement due to runoff from hill behind Buffalo St.
P75	City of Franklin	715 Buffalo St.	Construction on top of hill - Franklin Heights
P76	City of Franklin	723 Buffalo St.	Flooded Basement
P77	City of Franklin	600,700,800 Blocks of Buffalo St.	Flooding due to increased runoff from development
P78	City of Franklin	600,700,800 Blocks of Buffalo St.	city water pipes disturb stream
P79	City of Franklin	7th St. by Water Pumping Station	drain grate clogs due to debris
P80	City of Franklin	700 Block of Buffalo St.	drainage ditch sedimented in
P81	City of Franklin	700 Block of Buffalo St.	erosion, flooding due to new homes - Gurney Hill
P82	City of Franklin	700 and 800 Blocks of Buffalo St.	Flooding in backyard
P83	City of Franklin	700 Block of Buffalo St.	Excess runoff from wooded area behind Egbert St.
P84	City of Franklin	700 Block of Buffalo St.	Construction of Pump house runoff
P85	City of Franklin	700 Block of Buffalo St.	culvert and sewer too small
P86	City of Franklin	700 Block of Buffalo St.	culvert blocked with sediment
P87	Cranberry Twp	4024 Deep Hollow Rd	Blocked with Sediment - Property Flooding
P88	Cranberry Twp	Lower two Mile (322-5 mile uphill)	Streambank Erosion
P89	Cranberry Twp	Rt 257 to 322	Runoff too much for creek
P90	Cranberry Twp	Lower Two Mile (Deep Hollow)	Obstructions blocking flow
P91	Cranberry Twp	Rt 257-322	Retention Pond Not Holding Water for Cranberry Mall
P92	Cranberry Twp	Lower Two Mile Run/Harts Bridge	Creekbed is too Shallow, Fills up with Rock and Gravel
P93	Cranberry Twp	Lower Two Mile Run/Harts Bridge	River Bend is gouged out due to Soil Erosion
P94	Cranberry Twp	Lower Two Mile Run	Retention Basin at Cranberry Mall needs Revised to Hold Water
P95	Cranberry Twp	Lower Two Mile Run/Rt 257 Corridor	Retention Basins/Stormwater devices needs inspected
P96	Sandycreek Twp	Smith Run Between 3rd & 7th Streets	Flooding Caused by Inadequate Storm Sewers
P97	Sandycreek Twp	Davis Run	Undersized Culverts
P98	Sugarcreek Twp	2007 Keely Road	Erosion downstream of Keely Road crosspipe
SWP28	Richland Twp	Chrysler/Jeep Dealer	Water from SWM pond seeps through breastworks, runs toward highway.
E05	Cooperstown Boro	Maple Lane	Replace grass swales and drive pipes with storm sewers.
E06	Cooperstown Boro	Lakeview Drive	Replace grass swales and drive pipes with storm sewers.

Section V – Existing Stormwater Regulations and Related Plans

ID	MUNICIPALITY	LOCATION	DESCRIPTION
E07	Cooperstown Boro	Reisenman Drive	Replace grass swales and drive pipes with storm sewers.
F87, P99	City of Franklin	Davis Run beneath River Drive	Flooding due to undersized culverts.
F88, P98	City of Franklin	Smith Run culvert near Joy Plant	Smith Run surcharges the storm sewer network and floods the Joy plant.
F89	City of Franklin	Buffalo Street	Homes along Buffalo St. get flooded by a stream in upstream wooded area.
F91	City of Franklin	Spring Street	Stream overwhelms storm network during storms.
CHUB1, 2	Sandycreek Twp	Chub Run from Martino's to Franklin	Flooding and erosion.
CHUB7	City of Franklin	Chub Run inflow to storm sewers	Chub Run surcharges the storm sewer system during floods.

Table 5.1. Reported Problem Areas

ID	MUNICIPALITY	LOCATION	DESCRIPTION
O1	Barkeyville Bor	Slippery Rock Creek Adj Rt 8 & 208	Culvert under intersection
O2	Cherrytree Twp	Breedtown Rd T663	Large Culvert
O3	Cherrytree Twp	Cherrytree Rd T540	Large Culvert
O4	Cherrytree Twp	Shreve Rd T574	Large Culvert
O5	Cherrytree Twp	Trout Run Rd T578	Large Culvert
O6	Cherrytree Twp	Trout Run Rd T578	Large Pipe
O7	Cherrytree Twp	Stones Spring House Road T508	Stone Arch
O8	Cherrytree Twp	Fairview Rd T649	Large Culvert
O9	Cherrytree Twp	Fairview & Barker Road T649, T520	Bridges
O10	Cherrytree Twp	Cherrytree Rd T540	Large Pipe
O11	Cherrytree Twp	Lamey Road T518	Large Pipe
O12	Cherrytree Twp	Route 8 Cherrytree	Bridge
O13	Cherrytree Twp	Tarr woods T595	Culvert
O14	Cherrytree Twp	Demstown Graham T302	3 Culverts
O15	Cherrytree Twp	Old Route 8 T670	Culvert
O16	Cherrytree Twp	Black Rd T669	Culvert
O17	City of Franklin	Monkey Run @ Coefield Corners	Culvert
O19	City of Oil City	Cooper Run	
O20	City of Oil City	Willow/Alcorn	
O21	City of Oil City	Traction/Park Rd.	
O22	City of Oil City	Zemke Lane	
O23	Cranberry Twp	Lower Two Mile Run	Channel Dredging and Cleaning
O24	Cranberry Twp	Sage Run	Widening Channel
O25	Emlenton Bor	Hill St & 4th	Catch Basins
O26	Emlenton Bor	9th & Main	Open Pit
O31	Richland Twp	T-361	5' Pipe
O34	Utica Bor	Mill Creek Bridge	Rebuild Banks

Table 5.2. Reported Obstructions

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HYDRAULIC MODELING

Potential solutions were initially offered by the municipality or the project engineer for every identified problem based on a field view of the area. The locations of these problem areas were a factor used to determine which subwatersheds would be studied in detail. The analysis of the selected subwatersheds is presented in Section VI.

PROBLEM AREA ASSESSMENT

Upon completion of the modeling and analysis of the selected subwatersheds, conceptual solutions were proposed for each identified problem area. Some, but not all of the proposed solutions were based on the solutions offered by the municipalities on the Phase I questionnaires. The conceptual solutions to each identified problem and obstruction are presented in Appendix C.

Once the conceptual solutions were completed for each identified problem, an objective method was needed to assess the order in which the proposed solutions should be implemented. An analysis like this is necessary in order to prioritize where available funding is most needed. The chosen assessment system evaluates each problem area or obstruction independently of the others. This is more valuable than a ranking system which lists the problems in an order because it helps gauge the amount of resources that should be dedicated to addressing the existing problem areas and obstructions. ***However, as with any prioritization approach, this assessment could not encompass all factors in the decision making process and should be considered as a guide for future planning and funding efforts.***

A set of criteria was applied to determine the priority listing of each problem area. Criteria from a stormwater prioritization assessment completed in Columbus, Ohio were used to establish a system for prioritization (Tickle, 2008). Table 5.3 provides the list of criteria that were used to assess each problem area or obstruction. Based on the information available (Municipal input, site visit information; etc.) each problem (ID number in Tables 5.1 and 5.2 was assigned a rating between 1 and 10 for each of the six criteria. The six criteria were equally weighted in order to calculate a single relative rating between 1 and 10 for each problem.

Criteria	Description	Rating
Health & Safety	To what extent will the problem endanger human life?	1 to 10
Non-health & Safety Human Impact	How will the problem affect financial aspects of the surrounding areas?	1 to 10
Environmental Impact	To what extent will the problem contribute to erosion and sediment pollution?	1 to 10
Expected Life of Existing System	When will the system associated with the problem fail?	1 to 10
Frequency of Problem	How likely will the problem occur based on a 2-yr storm event?	1 to 10
Cost of Solution	Will the solution cost thousands, hundreds of thousands, or millions of dollars to resolve?	1 to 10

Table 5.3. Problem Area/Obstruction Rating Criteria (Adapted from Tickle, 2008)

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Each of the obstructions and problem areas have been categorized in one of three categories based on their composite score: 1) Highest Priority Problem, 2) Significant Problem, or 3) General Problem. Once calculations were performed, a composite rating between 7 and 10 would classify a problem area or obstruction as a Highest Priority Problem. A composite rating between 4 and 6.9 would classify a problem area or obstruction as a Significant Problem and a rating between 1 and 3.9 would be classified as a General Problem. Because each problem was evaluated independently, each municipality can use this assessment as the basis to develop their own problem area prioritization list.

The data sheets in Appendix C for these problem areas include a more descriptive overview and a more detailed recommended solution. Tables 5.4, 5.5, and 5.6 provide a list of Highest Priority, Significant, and General Problems respectively. All of the problem areas and obstructions are listed in the order of their relative ranking.

ID	Municipality	Location	Problem	Appendix C Page Location
F89	City of Franklin	S.R. 257 to S.R. 322	Flooding	53
P72-76, 78-86	City of Franklin	Buffalo Street (various locations)	Flooding	53
P77	City Of Franklin	Buffalo Street	Flooding	53
P27, P91, P94	VCCD, Cranberry Twp.	State Roads, Mall area	Flooding and Erosion	40
P6	City of Oil City	Union Street / Cornplanter Run	Flooding	78
P9 (O19)	City of Oil City	Cooper Run, East 8 th St.	Flooding	92
O12	Cherrytree Twp.	S.R. 8	Flooding and Erosion	5
P5	Cherrytree Twp.	Trout Run, T578	Flooding	16
P37a	Frenchcreek Twp.	French Creek Road	Erosion	56
P60	Sugarcreek Borough	S.R. 322 High School South	Flooding	124
P63	Sugarcreek Borough	McCleary Road at Bridge	Flooding	128

Table 5.4. Highest Priority Problem Listing

ID	Municipality	Location	Problem	Appendix C Page Location
O17, F90	City of Franklin	Monkey Run at Coefield Corners	Insufficient Conveyance Capacity	49
SWP28	Richland Township	Chrysler/Jeep Dealer	Maintenance Issue	114
P02	Barkeyville Boro	Cockain Road Culverts	Erosion	2
P40	Jackson Twp	Wolf Run on Rodger Road	Erosion	59
P24	City of Oil City	Dwyer Street	Insufficient Conveyance Capacity	99, 100
P10, O20	City of Oil City	Willow/Alcorn	Flooding and Erosion	83, 84, 88
P44	Oakland Twp	Davis Road	Flooding and Erosion	73
P65	Sugarcreek Boro	Shafer Run 1 Mile Upstream	Erosion	125

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ID	Municipality	Location	Problem	Appendix C Page Location
P72	City of Franklin	700 & 800 Blocks of Buffalo St	Flooding	53
P50	Plum Twp	Knepp Hill Road	Erosion	104
P47	Plum Twp.	McKinsey Road	Erosion	101
P64	Sugarcreek Boro	Route 8 Health	Insufficient Conveyance Capacity	123
P41b	Mineral Twp	Krizon Road	Erosion	6 2
P41d	Mineral Twp	Krizon Road	Insufficient Conveyance Capacity	69
P33	Cranberry Twp	Halls Run	Flooding and Erosion	33
P48	Plum Twp	Knightlanger Road	Erosion	103
P49	Plum Twp	Hiland Ave	Erosion	102
P73	City of Franklin	700 Block of Buffalo St	Maintenance Issue	53
P76	City of Franklin	723 Buffalo St	Insufficient Conveyance Capacity	53
P59	Sugarcreek Borough	Route 417 High School South	Flooding	130
P3, CHUB-7	City of Franklin	Chub Run between 14 th & 15 th	Insufficient Conveyance Capacity	48
P15	City of Oil City	Spring Street	Maintenance Issue	79
P69	Utica Boro	Mill Creek Flooding	Flooding	131
P74	City of Franklin	803 Buffalo Street	Insufficient Conveyance Capacity	53
F91	Cranberry Twp	Rt 257-322	Insufficient Conveyance Capacity	44
O10	Cherrytree Twp	Cherrytree Rd T540	Erosion	11
O24, P32	Cranberry Twp	Sage Run	Flooding	31
O26	Emlenton Boro	9 th & Main	Insufficient Conveyance Capacity	47
P51	Rouseville Boro	Hiland Ave	Flooding	117
P53	Sandycreek Twp	Morrison Run at Nightingale W of Rt. 8	Erosion	120, 121
P66	Sugarcreek Boro	Keely Road near Titus	Erosion	126
P78	City of Franklin	600, 700, 800 Blocks of Buffalo St	Flooding	53
P96	Rockland	Wilson Park	Erosion	115
P97	Rockland	Wilson Park	Erosion	116
O04a	Cherrytree Twp	Shreve Road	Erosion	13
O05	Cherrytree Twp	Trout Run Road T578	Erosion	16
O06	Cherrytree Twp	Trout Run Road T578	Erosion	15
O14	Cherrytree Twp	Demstown Graham T302	Erosion	22

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ID	Municipality	Location	Problem	Appendix C Page Location
P18	City of Oil City	Plummer Street	Insufficient Conveyance Capacity	90
P54, CHUB- 1,2	Sandycreek Twp	Chubb Run – Martino's to Franklin City	Erosion	119
P39	Jackson Twp	Sugar Creek near Talogo Rd	Erosion	60
P45	Oakland Twp	Race Track	Erosion	76
O04	Cherrytree Twp	Shreve Rd T574	Erosion	9
O07	Cherrytree Twp	Stones Spring House Road T508	Erosion	18
O09a	Cherrytree Twp	Barker Road	Erosion	19
O09d	Cherrytree Twp	Barker Road	Erosion	21
O15	Cherrytree Twp	Old Route 8 T670	Maintenance Issue, Erosion	14
P1, O1	Barkeyville Boro	Route 8, South of Route 208	Maintenance Issue	1
P21	City of Oil City	Harold Street	Insufficient Conveyance Capacity	96
P41e	Mineral Twp	Slatertown Road	Erosion	70
P52	Rouseville Boro	Bankson Rd	Erosion	118
O02	Cherrytree Twp	Breedtown Rd T663	Erosion	17
O08	Cherrytree Twp	Fairview Rd T649	Erosion	10
O14b	Cherrytree Twp	Dempseytown Grisham Road	Erosion	12
O16	Cherrytree Twp	Black Rd T669	Erosion	8
P36	Frenchcreek Twp	French Creek Rd T-356	Flooding and Erosion	54, 55
P92, P93	Cranberry Twp	Lower Two Mile Run/Harts Bridge	Flooding and Erosion	34
O25b	Emlenton	Hill Street	Insufficient Conveyance Capacity	46
O31	Richland Twp	T-361	Flooding	113
P08	City of Oil City	Hasson Park	Erosion	77
P30	Cornplanter Twp	Russell Corner Rd – Oil Creek	Insufficient Conveyance Capacity	29
O03	Cherrytree Twp	Cherrytree Rd. T540	Erosion	7
P67	Utica Boro	French Creek Flooding	Flooding	135
P68	Utica Boro	Mill Creek Stream	Erosion	132
P87, O23, P31	Cranberry Twp	4024 Deep Hollow Road	Flooding	35

Table 5.5. Significant Problems List

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ID	Municipality	Location	Problem	Appendix C Page Location
E5	Cooperstown Borough	Maple Lane	Insufficient Conveyance Capacity	23
O11	Cherrytree Twp	Lamey Road T518	Erosion	6
P22	City of Oil City	Summit Street	Insufficient Conveyance Capacity	80
P23	City of Oil City	Halyday Street	Insufficient Conveyance Capacity	98
P41c	Mineral Twp	Kimbel Road	Maintenance Issue	68
P41f	Mineral Twp	Slatertown Road	Erosion	65
P41g	Mineral Twp	Gadsby Road	Erosion	71
P42	Mineral Twp	Henderson Station Road	Maintenance Issue	64
P42b	Mineral Twp	Henderson Station Road	Maintenance Issue	72
E6	Cooperstown Boro	Lakeview Drive	Insufficient Conveyance Capacity	25
E7	Cooperstown Boro	Reisenman Drive	Insufficient Conveyance Capacity	24
P19	City of Oil City	E. Eight Drive	Insufficient Conveyance Capacity	95
P29	Cornplanter Twp	Scott Drive	Insufficient Conveyance Capacity	12, 28
P41a	Mineral Twp	Palm Hill Road	Erosion	67
P43	Mineral Twp	Reeds Furnace Road	Maintenance Issue	63
P61	Sugarcreek Boro	Sugar Creek at Orr's to Weaver Street	Unidentified	129
P13	City of Oil City	Oliver Manor	Insufficient Conveyance Capacity	81
P43b	Mineral Twp	Reeds Furnace Road	Maintenance Issue	63
O13	Cherrytree Twp	Tarr Woods T595	Erosion	3
P70, O34	Utica Boro	Loosing Mill Creek Bridge	Erosion	133
O12a	Cherrytree Twp	S.R. 8	Erosion	5
P14	City of Oil City	Marina	Erosion	93
P20	City of Oil City	Mylan Street	Maintenance Issue	88
P46	Oakland Twp	Prather Run/East Branch Sugarcreek	Flooding	74
F88, P98	City of Franklin	Smith Run Culvert Near Joy Plant	Flooding	52
P37	Frenchcreek Twp	Mapledale	Insufficient Conveyance Capacity	578, 58
P16	City of Oil City	Colbert Ave	Unidentified	87
P34	Cranberry Twp	Horse Creek	Unidentified	32

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ID	Municipality	Location	Problem	Appendix C Page Location
O09c	Cherrytree Twp	Unidentified	Erosion	20
P7	City of Oil City	Colbert Ave Streams	Maintenance Issue	85, 86
P41h	Mineral Twp	Henderson Station Road	Erosion	66
F87, P99	City of Franklin	Davis Run beneath River Drive	Flooding	51
P35	Cranberry Twp	Sandy Creek	Erosion	32
P95, P28	Cranberry Twp	Two Mile Run Storm Pond	Flooding	43
O25	Emlenton Boro	Hill St & 4 th	Unidentified	45
P17	City of Oil City	Moran Street	Unidentified	82
P25	City of Oil City	Spruce Street	Unidentified	91
P75	City of Franklin	715 Buffalo St	Unidentified	53

Table 5.6. General Problems List

Figures 5.2 and 5.3 on the following pages show the composite rating for all of the reported problem areas and obstructions throughout the entire County.

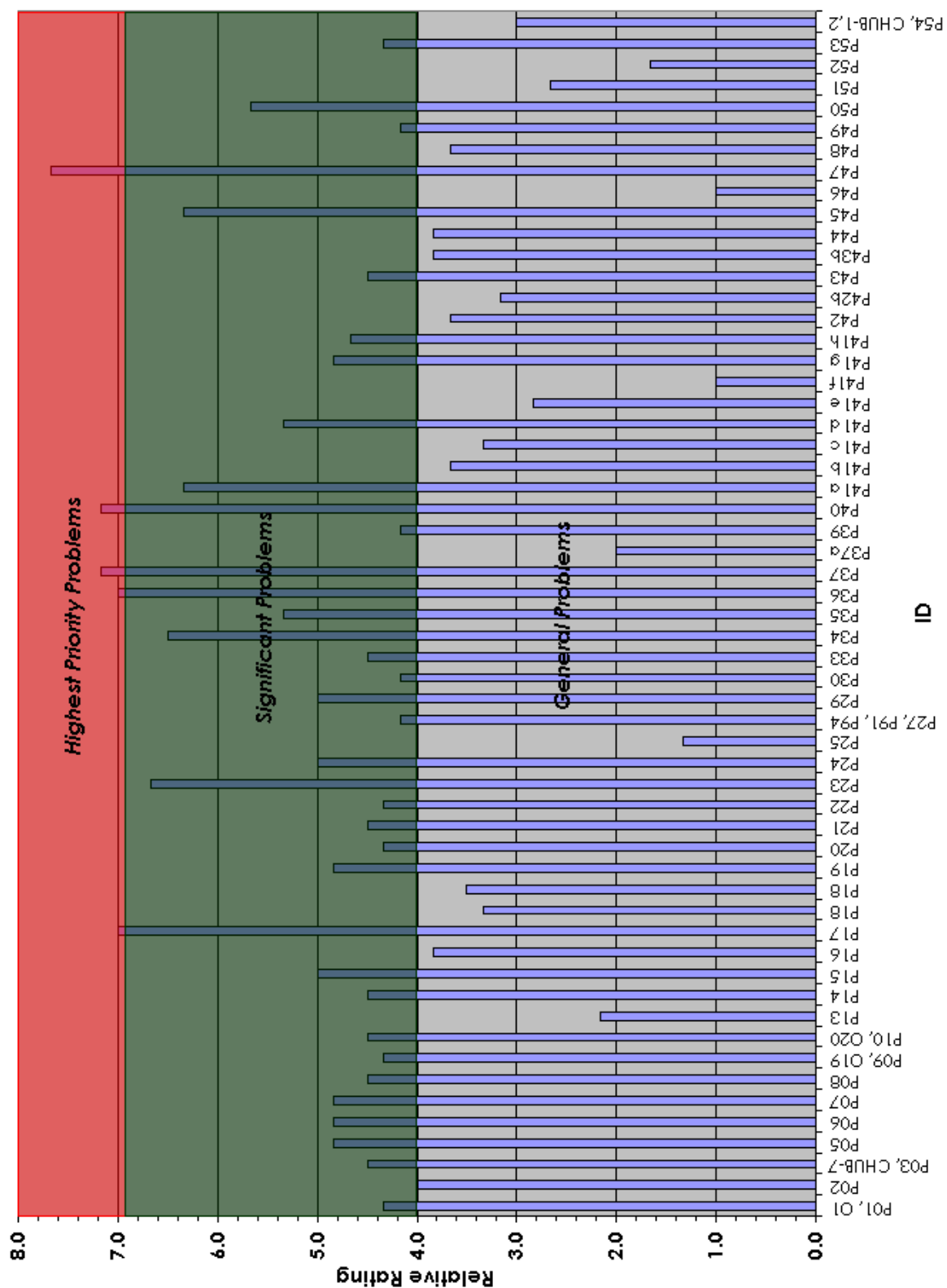
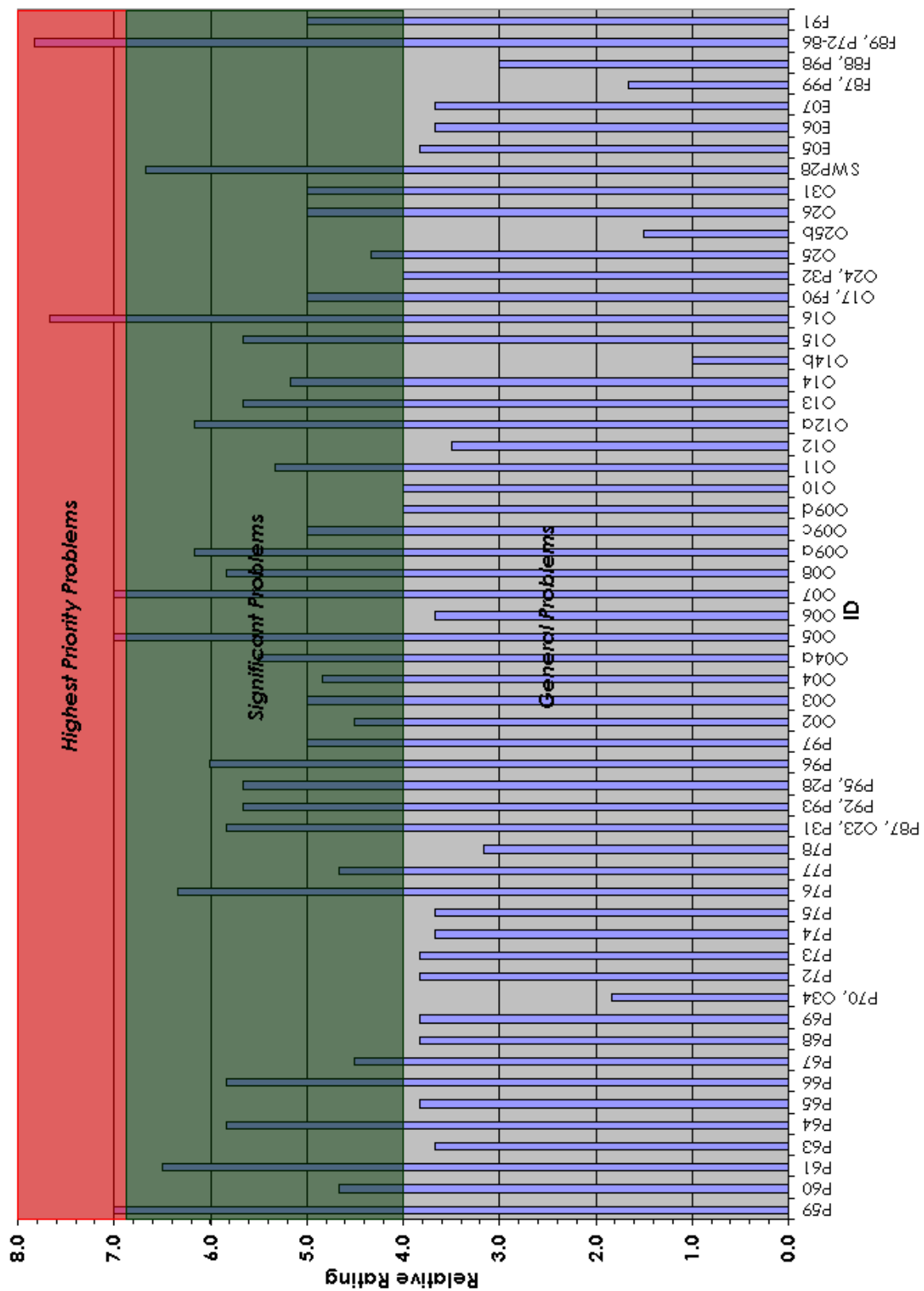


Figure 5.2. Problem Area/Obstruction Rating

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Section V – Existing Stormwater Regulations and Related Plans

RECOMMENDATIONS

The reported stormwater problems within the study area can be attributed to one or more of several principal causes:

1. The existing storm drain system has insufficient capacity.
2. There is an incomplete collection and conveyance system or a lack of a formal/comprehensive system.
3. Maintenance is required on an existing system (i.e. catch basin inlets become plugged and local flooding occurs).
4. Problem areas are located in the floodplain area.

In addition, the problem areas mentioned in this section are more pronounced in the more populated/developed areas. This is most likely due to encroachments into floodplain areas and undersized culverts or bridges. Also, a large number of these stormwater related problems have been traced back to uncontrolled runoff from local and upstream areas, inadequate culverts or bridges, and obstructions in the system that are blocking the natural flow of stormwater.

This study has identified some drainage problems that occur on a yearly basis. Continued improper development within the County will amplify these problems. Remedial actions will be necessary to correct existing drainage problems. In the long term, a comprehensive approach is needed to tackle these problems. This approach will have to incorporate regulations and development standards into local zoning, consider both on-site and off-site drainage, provide a consistent approach between communities, use natural elements for the transport and storage of stormwater, consider both quantity and quality of water, and treat the watershed as a whole.

Stormwater master planning is one way to address all of the needs and potential threats to a watershed. However, implementation of these practices can be difficult and may not be economically feasible for many communities. HRG, in cooperation with the Venango County Regional Planning Commission, is taking the lead to develop economical solutions that address stormwater runoff issues that lead the industry and provide the regulatory community with solutions that meet EPA and DEP standards. Looking ahead, it is expected that the status of the current stormwater infrastructure will keep deteriorating with time. In addition to imposing stronger regulations to control new development, increased expenditures for maintenance and other improvements will be necessary to prevent the systems from deteriorating faster than the ability to fix and maintain them.

While a certain amount of flooding is natural in streams during heavy rain, careful maintenance should prevent serious problems with flooding and erosion. Simple maintenance activities include:

- Watching for any changes that might be occurring within the stream bed or banks
- Keeping the stream clear of obstructions
- Removing litter and rubbish
- Monitoring sources of upstream pollution
- Removing plants that impede flow
- Keeping clear any secondary overland flow paths that stormwater or stream flow takes during floods
- Preventing bank erosion by protecting and maintaining vegetation near streambanks
- Clearing away animal droppings
- Sweeping paths rather than hosing them

Section V – Existing Stormwater Regulations and Related Plans

- Discharging stormwater from impervious surfaces, such as paths and driveways into gardens, lawns and rainwater planters

Section VI – Technical Analysis - Modeling

TECHNICAL APPROACH

To provide technical guidance in the Act 167 planning process, hydrologic models were prepared for specific watersheds identified by the municipalities, the county and Pennsylvania Department of Environmental Protection (DEP). The results from these models increase the overall understanding of watershed response to rainfall and help guide policy. Through the development and analysis of a hydrologic model, effective and fair regulations can be applied on a county-wide basis, while addressing specific issues identified by the individual communities in Venango County. The hydrologic methodology used in the technical approach is the Natural Resource Conservation Service (NRCS) Rainfall-Runoff Method described in various NRCS publications (NRCS, 2008a). This method was chosen since it is the most common method used by designers in Pennsylvania and has widely available data (NRCS, 2008b). Additionally, this method is the basis for which many of the guidelines were developed in the PA Stormwater BMP Manual. The calculations for this methodology were performed with HEC-HMS, the US Army Corps of Engineers' Hydrologic Modeling System.

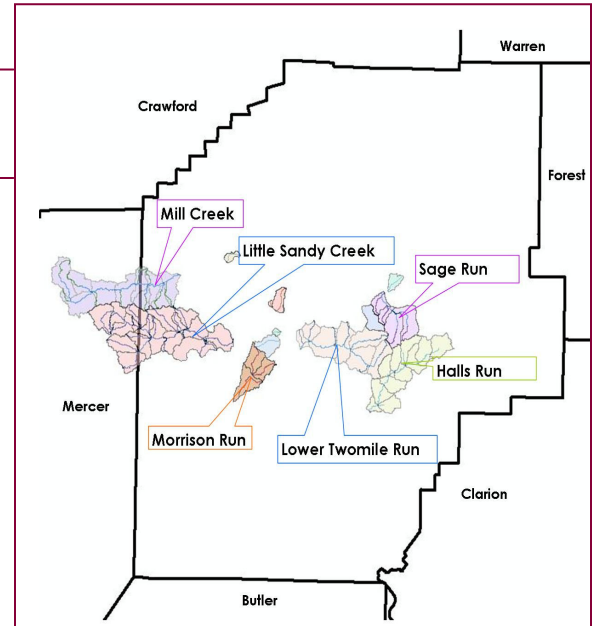
The modeling approach in this study was to:

1. Establish a reasonable estimate of rainfall-runoff response under existing conditions,
2. Establish a reasonable estimate of rainfall-runoff response under an assumed future condition land development,
3. Provide an examination of the impact with the implementation of guidelines from the PA Stormwater BMP Manual (i.e., Design Storm Method and Simplified Method), and finally
4. Develop stormwater management districts where it is determined necessary to do so.

Information from PAC meetings has been incorporated to direct the focus of this modeling effort and to ensure the most current DEP regulations are successfully incorporated throughout the entire county.

HYDROLOGIC MODEL PREPARATION

Six watersheds within the county were selected for hydrologic modeling: Halls Run, Little Sandy Creek, Lower Twomile Run, Mill Creek, Morrison Run, and Sage Run. Six tributaries were also selected for hydrologic modeling: E003, P004, F88, F89, P59/P91, and P60. These watersheds were delineated into subwatersheds based on problem areas, significant obstructions, and natural subwatershed divides. The delineation of these subwatershed areas created points of interest at junctions where the subwatersheds were hydraulically connected in the HEC-HMS model.



Section VI – Technical Analysis – Modeling

HALLS RUN MODEL

The Halls Run watershed has a drainage area of 11.4 square miles and was divided into 12 subwatersheds for the HEC-HMS model. *Figure 6.1* shows the Halls Run subwatersheds and cumulative discharge points.

LITTLE SANDY CREEK MODEL

The Little Sandy Creek watershed has a total drainage area of 21.8 square miles. A large portion (about 8.4 mi²) of this watershed lies within Mercer County. The watershed was divided into 18 subwatersheds for the HEC-HMS model. *Figure 6.2* shows the Little Sandy Creek subwatersheds and cumulative discharge points.

LOWER TWOMILE RUN MODEL

The Lower Twomile Run watershed has a total drainage area of 13.1 square miles. The watershed was divided into seven subwatersheds for the HEC-HMS model. *Figure 6.3* shows the Lower Twomile Run subwatersheds and cumulative discharge points.

MILL CREEK MODEL

The Mill Creek watershed has a total drainage area of 15.3 square miles. A large portion (about 10.5 mi²) of this watershed lies within Mercer County. The watershed was divided into 10 subwatersheds for the HEC-HMS model. *Figure 6.4* shows the Mill Creek subwatersheds and cumulative discharge points.

MORRISON RUN MODEL

The Morrison Run watershed has a total drainage area of 3.9 square miles. The watershed was divided into three subwatersheds for the HEC-HMS model. *Figure 6.5* shows the Morrison Run subwatersheds and cumulative discharge points.

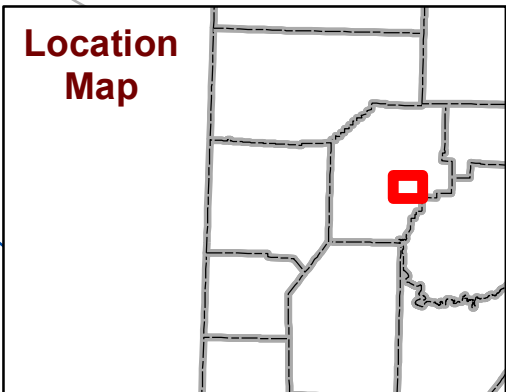
SAGE RUN MODEL

The Sage Run watershed has a total drainage area of 5.4 square miles. The watershed was divided into four subwatersheds for the HEC-HMS model. *Figure 6.6* shows the Sage Run subwatersheds and cumulative discharge points.

VENANGO TRIBUTARIES MODEL

The Venango Tributaries model includes six tributaries containing documented problem areas throughout Venango County. The six tributaries have a total drainage area of 4.7 square miles. The tributaries were divided into six subwatersheds for the HEC-HMS model. *Figure 6.7* shows the Venango Tributaries subwatersheds and cumulative discharge points.

Location
Map



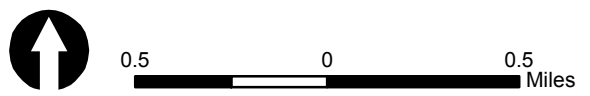
[BUILDING RELATIONSHIPS.
DESIGNING SOLUTIONS.]

Figure 6.1
Halls Run HEC-HMS Model
Venango County, Pennsylvania

- Discharge Points
 - USGS Gauges
 - ~ Streams
 - Water bodies
 - ~ Limited Access
 - ~ Highway
 - ~ Major Road
 - ~ Local Road
 - HEC-HMS Subbasins
 - Municipalities
 - Counties
- Elevation**
- High : 1640 Feet
- Low : 1070 Feet

NOTE:
Portions of this map are provided for spatial reference only.
They were generated from existing data sources and may
contain discrepancies that have not been corrected as part
of this Act 167 Plan.

DATA SOURCES:
Halls Run Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - PAMAP



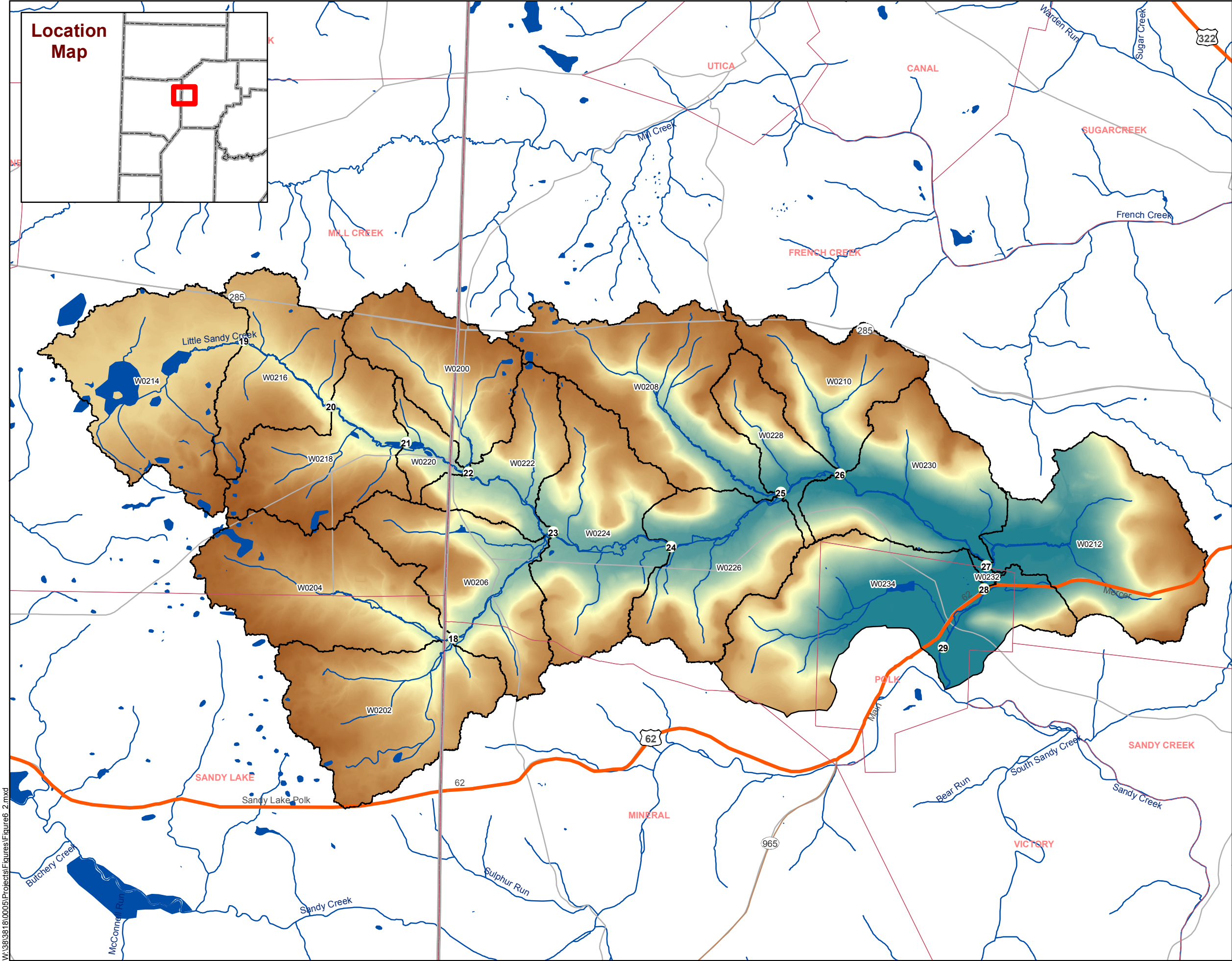
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Figure 6.2

Little Sandy Creek HEC-HMS Model Venango County, Pennsylvania

- Discharge Points
- USGS Gauges
- ~ Streams
- Water bodies
- ≡ Limited Access
- ≡ Highway
- ≡ Major Road
- ≡ Local Road
- HEC-HMS Subbasins
- Municipalities
- Counties

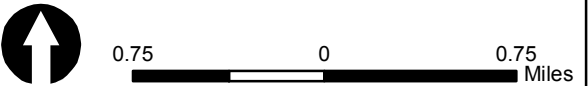
Elevation

High : 1570 Feet

Low : 1030 Feet

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DATA SOURCES:
Little Sandy Creek Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - PAMAP

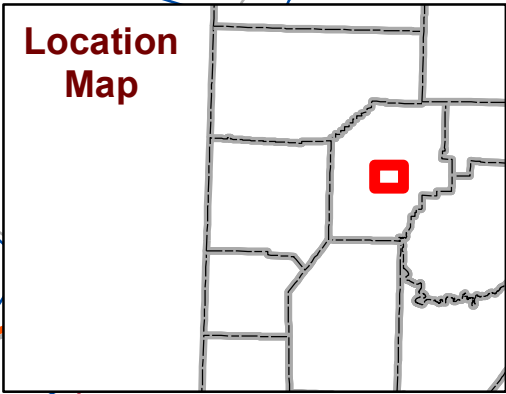


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Location
Map



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Figure 6.3
Lower Two
Mile Run HEC-HMS Model
Venango County, Pennsylvania

- Discharge Points
- USGS Gauges
- ~ Streams
- Water bodies
- ≡ Limited Access
- ≡ Highway
- ≡ Major Road
- ≡ Local Road
- HEC-HMS Subbasins
- Municipalities
- Counties

Elevation

High : 1540 Feet
Low : 950 Feet

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of this Act 167 Plan.

DATA SOURCES:
Lower Two Mile Run Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - PAMAP



0.5 0 0.5
Miles

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Location
Map



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Figure 6.4
Mill Creek HEC-HMS Model
Venango County, Pennsylvania

- Discharge Points
 - USGS Gauges
 - ~ Streams
 - Water bodies
 - ≡ Limited Access
 - ▬ Highway
 - ▬ Major Road
 - ▬ Local Road
 - HEC-HMS Subbasins
 - Municipalities
 - Counties
- Elevation**
- High : 1580 Feet
- Low : 1020 Feet

NOTE:
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DATA SOURCES:
Mill Creek Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - PAMAP



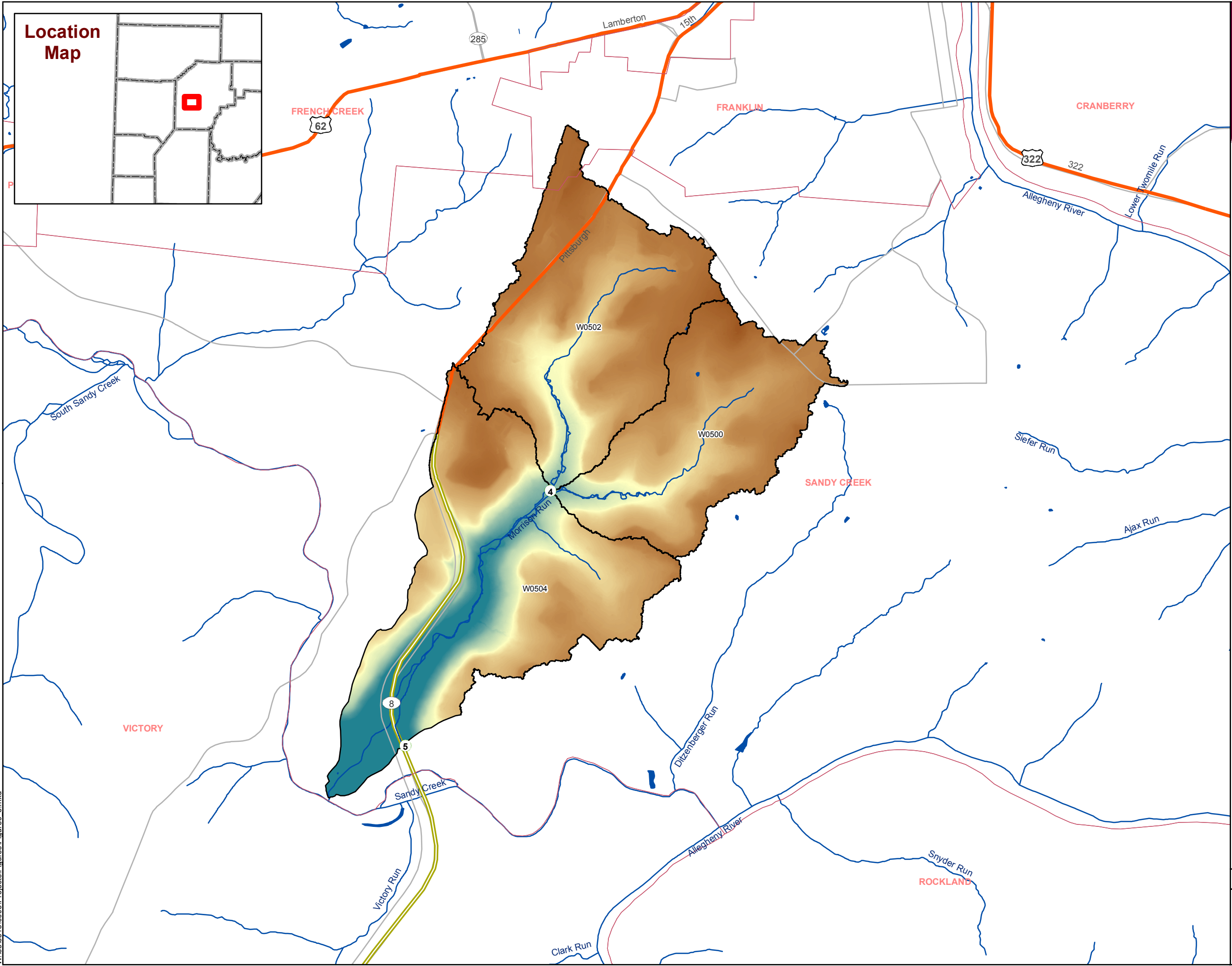
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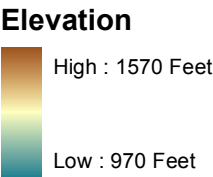
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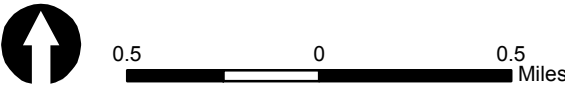
Figure 6.5
Morrison Run HEC-HMS Model
Venango County, Pennsylvania

- Discharge Points
- USGS Gauges
- ~ Streams
- Water bodies
- Limited Access
- Highway
- Major Road
- Local Road
- HEC-HMS Subbasins
- Municipalities
- Counties



NOTE:
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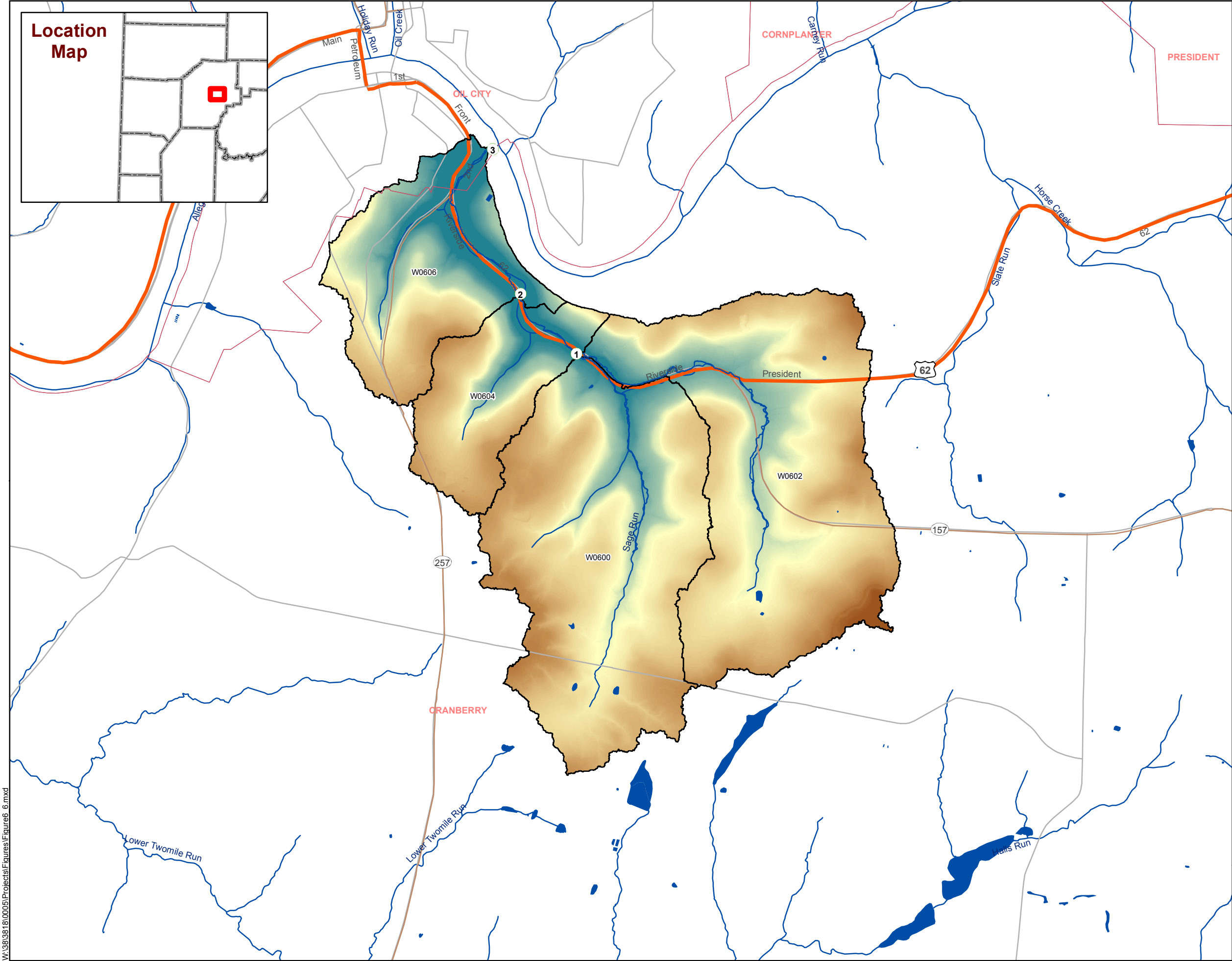
DATA SOURCES:
Morrison Run Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - PAMAP



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Figure 6.6

Sage Run HEC-HMS Model Venango County, Pennsylvania

- Discharge Points
- USGS Gauges
- ~ Streams
- Water bodies
- ≡ Limited Access
- ≡ Highway
- ≡ Major Road
- ≡ Local Road
- HEC-HMS Subbasins
- Municipalities
- Counties

Elevation

High : 1600 Feet

Low : 980 Feet

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of this Act 167 Plan.

DATA SOURCES:
Sage Run Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - PAMAP

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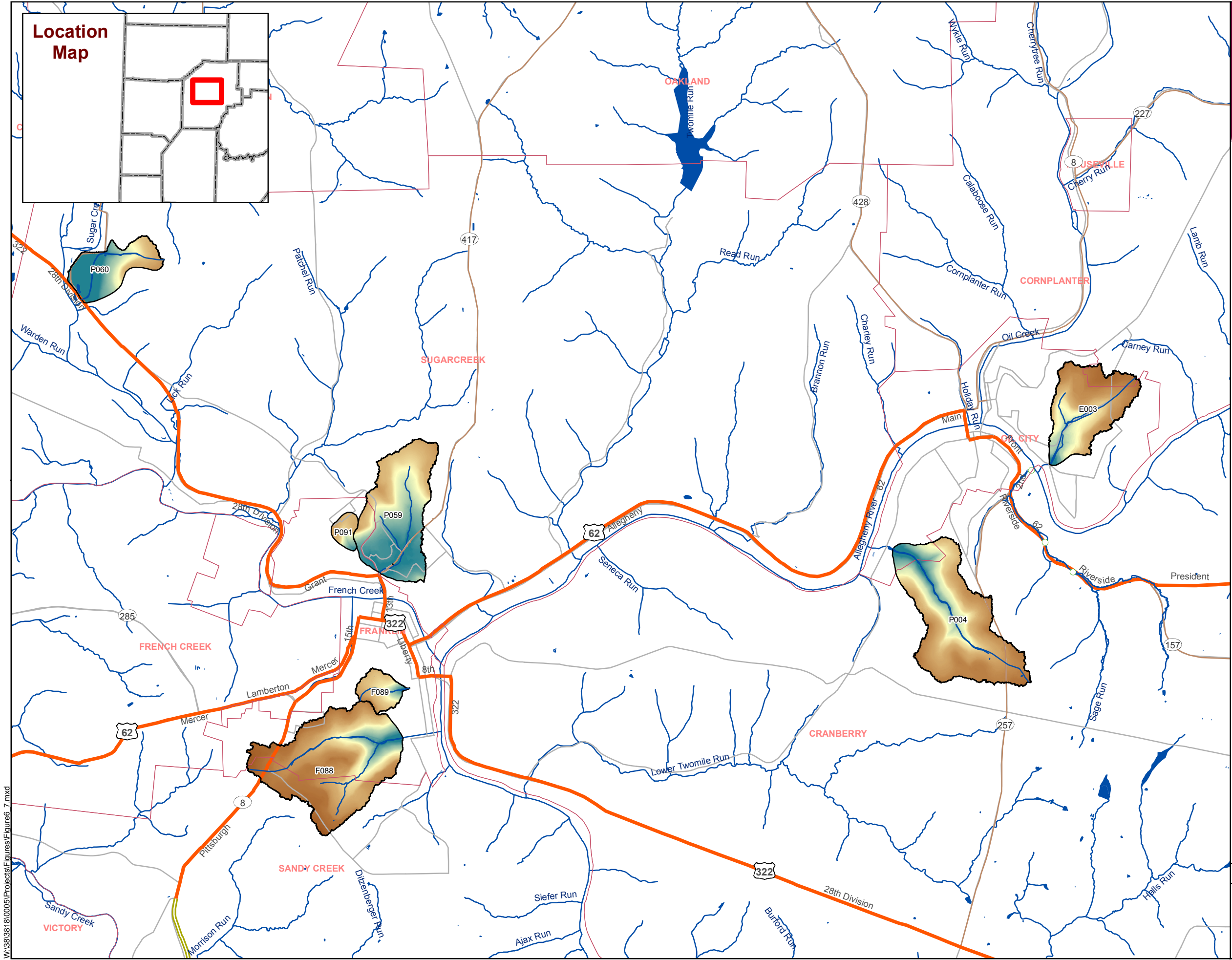
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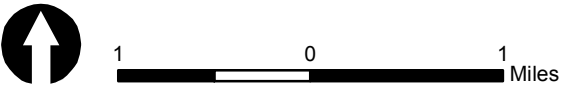
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Figure 6.7
E003, F88, F89, P004, P59/P91, P60
HEC-HMS Models
Venango County, Pennsylvania

- USGS Gauges
 - Streams
 - Water bodies
 - Limited Access
 - Highway
 - Major Road
 - Local Road
 - HEC-HMS Subbasins
 - Municipalities
 - Counties
- Elevation**
- High : 1570 Feet
 - Low : 980 Feet

NOTE:
Portions of this map are provided for spatial reference only.
They were generated from existing data sources and may
contain discrepancies that have not been corrected as part
of this Act 167 Plan.

DATA SOURCES:
E003, F88, F89, P004, P59/P91, P60 Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - PAMAP



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HYDROLOGIC MODEL PARAMETERS

The various parameters entered into the hydrologic models include subwatershed area, soil-type, land cover, lag time, reach lengths and slopes, reach cross sectional dimensions, and design rainfall depths. These parameters are discussed in further detail in the technical appendix. A brief description of these components follows.

RAINFALL DATA

Rainfall data used in this modeling effort incorporates rainfall runoff data from the NOAA Atlas 14. NOAA Atlas 14 provides the most up to date precipitation frequency estimates, with associated confidence limits, for the United States and is accompanied by additional information such as temporal distributions and seasonality. Rainfall depths were obtained from a single point at the approximate geographic center of the county. The following table provides the rainfall estimates used for various design storm frequencies for Venango County (NOAA, 2008):

Design Storm (years)	24-hr Rainfall Depth (in)
2	2.45
10	3.44
25	4.07
50	4.58
100	5.12

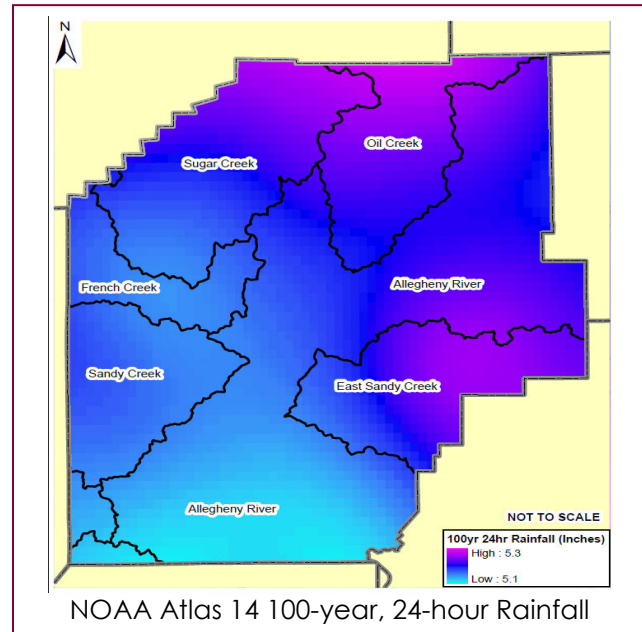
Table 6.1. Rainfall Values for Venango County

It was assumed in all of the following analyses that these single rainfall quantities could be applied uniformly over the entire watershed area. Additionally, the rainfall quantities were applied to the NRCS Type II storm distribution. Although this combination of Atlas 14 data with the NRCS Type II storm distribution results in a relatively conservative rainfall pattern, this approach is consistent with the guidelines in PA Stormwater BMP Manual (DEP,2006).

SUBWATERSHED AREA

Generally, the subwatershed area for the modeled watersheds was 1-2 mi². The drainage areas may be slightly larger or smaller depending on hydrologic characteristics and location of problem areas. Subwatersheds with an area less than one square mile were included in the model if they formed a junction between two larger basins or were tributary to a defined problem area. The delineations were based on Lidar data provided by PASDA (2007). This data has a vertical accuracy of 37.0 centimeters.

Basins with drainage area outside of Venango County were beyond the scope of study so they were not studied at the same level of detail as portions of the watershed within the county. Mill Creek and Little Sandy Creek are modeled watersheds within Venango County that extend into



Section VI – Technical Analysis – Modeling

Mercer County. The land use for the subbasins within Mercer County was assumed to be constant for existing and future conditions.

SOILS

Soil properties, specifically infiltration rate and subsurface permeability, are an important factor in runoff estimates. Runoff potential of different soils can vary considerably. Soils are classified into four Hydrologic Soil Groups (A, B, C, and D) according to their minimum infiltration rate (SCS 1986). HSG A refers to soils with relatively high permeability and favorable drainage characteristics; HSG D soils have relatively low permeability and poor drainage characteristics. The runoff potential increases dramatically in order of group A (lowest), B, C, and D (highest). Soil cover data was used in conjunction with land use cover data within GIS to develop composite curve numbers for each subwatershed in the models.

Table 3.5 show the relative percentage of hydrologic soil groups in Venango County. Generally, the soils with the highest runoff potential also correspond to the location of many of the counties' identified problem areas.

LAND USE

Existing land use was derived from the Land Use provided by Venango County Planning Department. This data was converted to land uses that correspond to NRCS curve number tables (SCS, 1986). The land use categories that were used are listed in Table 6.2.

Future land uses for the year 2020 were also provided by the Venango County Planning Department and were later digitized for the purposes of this study. The future land use data reflects an estimate of future land use considering current trends and policies.

Land Use	Existing Land Use		Proposed Land Use		Change Future - Existing
	Acres	%	Acres	%	%
Brush ¹	1.3	0.0%	1.3	0.0%	0.0
Commercial and Business	339.1	0.7%	702.2	1.5%	0.8
Contoured Row Crops ¹	2174.0	4.6%	2174.5	4.6%	0.0
Industrial	132.0	0.3%	86.4	0.2%	-0.1
Meadow ¹	298.9	0.6%	298.8	0.6%	0.0
Open space ¹	2787.4	5.8%	3501.2	7.3%	1.5
Pasture ¹	7146.8	15.0%	6463.7	13.5%	-1.5
Residential - 1 acre	2168.9	4.5%	5227.2	11.0%	10.6
Residential - 1/2 acre	495.9	1.0%	1021.5	2.1%	1.1
Residential - 1/8 acre	661.6	1.4%	943.1	2.0%	0.6
Water	82.1	0.2%	82.2	0.2%	0.0
Woods ¹	31417.4	65.9%	27203.6	57.0%	-8.9
Total	47705.6	100.0	47705.6	100.0%	n/a

Notes: ¹ In Good Condition

Table 6.2. Estimated Existing and Future Land Use in the Modeled Watersheds

Section VI – Technical Analysis – Modeling

within Venango County

LAG TIME

Lag time is the transform routine when using the NRCS Curve Number Runoff Method. Lag can be related to time of concentration using the empirical relation:

$$T_{Lag} = 0.6 * T_C$$

Lag time values for the subwatersheds were based on NRCS Lag Equation and altered as described in Appendix A:

$$T_{Lag} = L^{0.8} \frac{(S + 1)^{0.7}}{1900\sqrt{Y}}$$

Where: T_{Lag} = Lag time (hours)

L = Hydraulic length of watershed (feet)

Y = Average overland slope of watershed (percent)

S = Maximum retention in watershed as defined by: $S = [(1000/CN) - 10]$

CN = Curve Number (as defined by the NRCS Rainfall-Runoff Method)

For comparison purposes, a lag time was also calculated for each subwatershed using the TR-55 segmental method. Given the rural landscape of Venango County, the best estimate for time of concentration calculation was provided by the NRCS lag equation.

INFILTRATION AND HYDROLOGIC LOSS ESTIMATES

Infiltration and all other hydrologic loss estimates (e.g., evapotranspiration, percolation, depression storage, etc.) were modeled using the standard initial abstraction in the NRCS Rainfall-Runoff Method (i.e., $I_a = 0.2S$) for the existing conditions and future conditions models. For the future conditions with stormwater controls model, these losses were taken into account using a modified initial abstraction value. This modified value was developed to be consistent with, and account for, the volume removal criteria under the Design Storm Method and the Simplified Method (CG-1 and CG-2). A detailed explanation of this modeling effort is described in Appendix A.

REACH LENGTHS, SLOPES, AND CROSS SECTION DIMENSIONS

Reach lengths and slopes were determined within GIS. Channel baseflow widths and depths for each river reach were estimated based on drainage area and percent carbonate using the methodology outlined in *Development of Regional Curves Relating Bankfull-Channel Geometry and Discharge to Drainage Area for Streams in Pennsylvania and Selected Areas of Maryland* (USGS, 2005). Dimensions for the overbank area were visually determined from FEMA floodplains or visual inspection of topographic data. Figure 6.8 shows the dimensions as they are approximated.

Section VI – Technical Analysis – Modeling

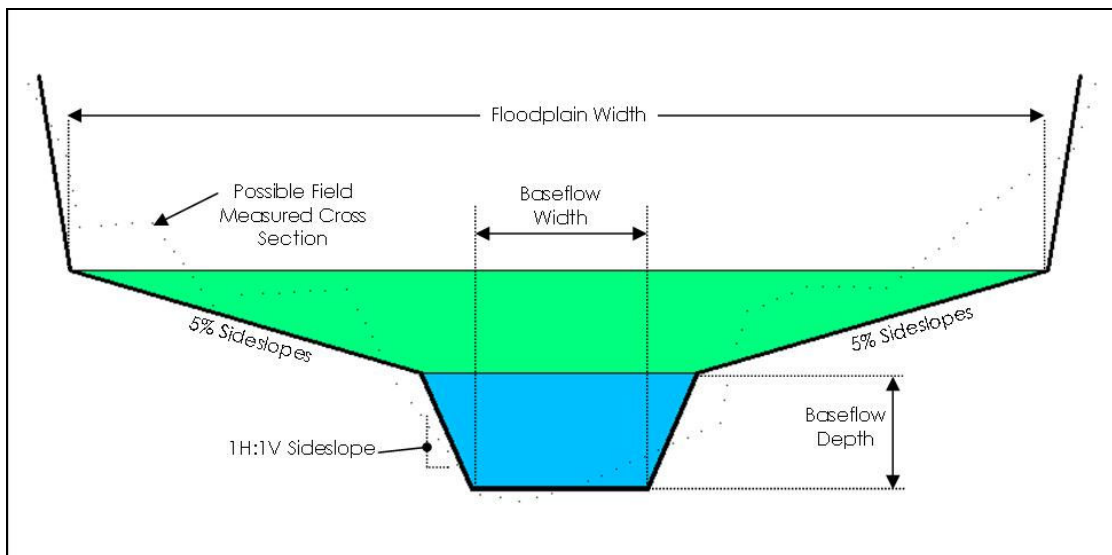


Figure 6.8. Cross Sections Used for Reaches in HEC-HMS Model

The reaches were modeled using the Muskingum-Cunge routing procedure. This procedure is based on the continuity equation and the diffusion form of the momentum equation. Manning's Roughness Coefficient n values were assumed to be 0.055 in channel; overbank channel values were assumed to be 0.08. When necessary for calibration, Manning's n values and the overbank sideslopes were altered so that realistic discharge values could be obtained. The data used for each specific reach is available within the HEC-HMS Model.

MODEL CALIBRATION

The HEC-HMS models incorporate a number of user-defined variables to generate runoff hydrographs. The accuracy of the model remains unknown unless it is calibrated to another source of runoff information. Possible sources of information include stream gage data, high water marks (where detailed survey is available to facilitate hydraulic analysis), and other hydrologic models. The most desirable source of calibration information is stream gage data as this provides an actual measure of the runoff response of the watershed during real rain events.

There are six USGS stream gages with adequate record located in Venango County; however none of these gages are located within the limits of the modeled watersheds. The following table lists these gages and their respective statistics.



USGS Gage 03025500 Allegheny River at
Franklin, PA
Source: USGS, 2010

Section VI – Technical Analysis – Modeling

USGS Stream Gage No.	Site Name	Drainage Area mi ²	Number of Gage Years at Gage	Used in HEC-HMS Model
03020500	Oil Creek at Rouseville, PA	283	99	Not used
03024000	French Creek at Utica, PA	1,028	77	Not used
03025000	Sugar Creek at Sugarcreek, PA	166	47	Not used
03025200	Patchel Run near Franklin, PA	5.67	18	Not used
03025500	Allegheny River at Franklin, PA	5,982	96	Not used
03026400	Richey Run at Emlenton, PA	5.88	19	Not used

Table 6.3. USGS Stream Gages in Venango County

There are no gages within the watersheds being analyzed for this study. When no stream gage data is available as is the case with the modeled watersheds within Venango County, the next most desirable source of data for purposes of comparison is other hydrologic studies prepared by local, state, or federal agencies. FEMA Flood Insurance Studies (FIS) often provide discharge estimates at specific locations within FEMA floodplains. The estimates provided in FEMA FISs are valid sources for comparison but should be carefully considered when used for calibration since they are sometimes dependent on outdated methodology, or focus exclusively on the 100-year event for flood insurance purposes.

The third available source of information that may be used for calibration is regression equation estimates. The regression equations were developed on the basis of peak flow data collected at numerous stream gages throughout Pennsylvania. This procedure is the most up-to-date method and takes into account watershed average elevation, carbonate (limestone) area, and minor surface water storage features such as small ponds and wetlands. The methodology for developing regression equation estimates within Pennsylvania is outlined in USGS Scientific Investigations Report 2008-5102 (USGS, 2008). Mean Elevation, Percent Carbonate Rock, and Percent Storage, the applicable parameters within Venango County, were calculated using GIS from layers supplied from USGS Digital Elevation Model (DEM) data, Environmental Resources Research Institute (1996), and USGS (2008).

The target flow rates were determined from one of these three sources. The HEC-HMS models were then calibrated to the target flow rates at the overall watershed level, at subwatersheds where significant hydrologic features were identified (e.g., confluences, dams, USGS Gages), and at each individual subbasin. This approach was used so that a flow value anywhere in the model would compare favorably to the best available data source. The parameters of calibration for the entire overall watershed were the antecedent runoff condition, lag time, and reach routing coefficients. Detailed calibration results are provided in *Appendix A*.

Target flow rates for the Venango Tributaries Model were not determined since the corresponding drainage area was not within the limits of the USGS Regression Equations. Instead, the curve number, area, watershed slope, and longest flow length was calculated for each modeled watershed. An average antecedent runoff condition from Halls Run, Little Sandy Creek, Lower Twomile Run, Mill Creek, Morrison Run, and Sage Run was determined for each storm event. The average antecedent runoff condition from the watersheds listed above was applied to the calculated curve number for each modeled watershed within the Venango Tributaries Model. The flow rates generated from this method were used as the calibrated flow rates.

The following figures (*Figures 6.9-6.14*) show the overall watershed calibration results for Halls Run, Little Sandy Creek, Lower Twomile Run, Mill Creek, Morrison Run, Sage Run, and the Venango

Section VI – Technical Analysis – Modeling

Tributaries modeled watersheds. As can be shown, the calibration results are in general agreement with the range of values for other hydrologic studies.

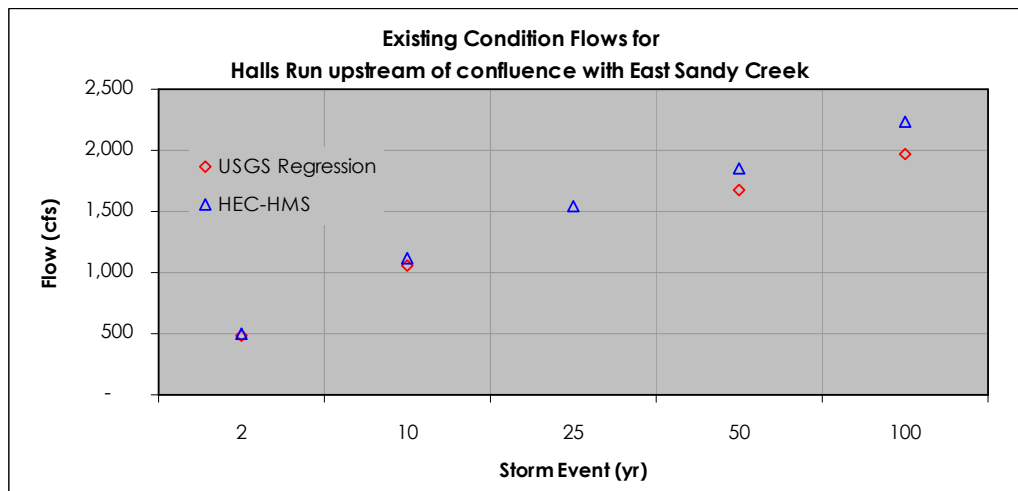


Figure 6.9

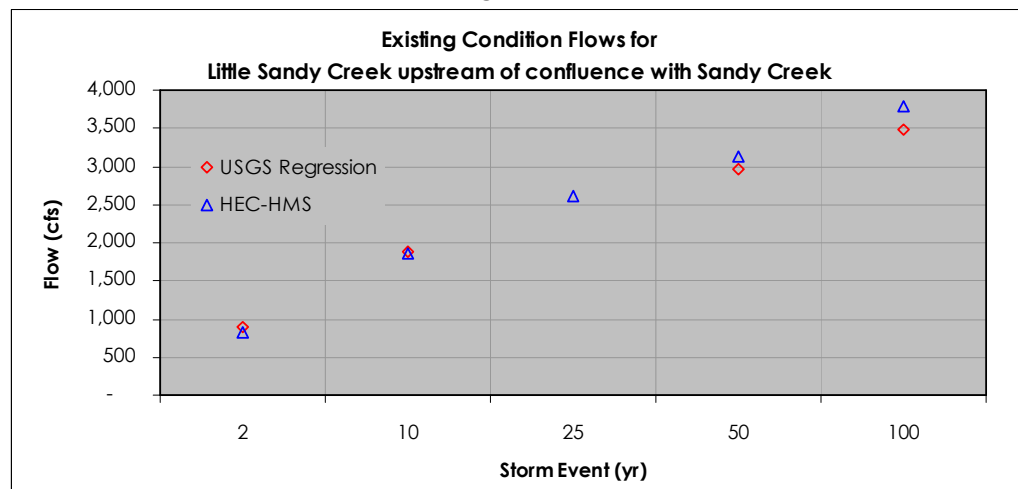


Figure 6.10

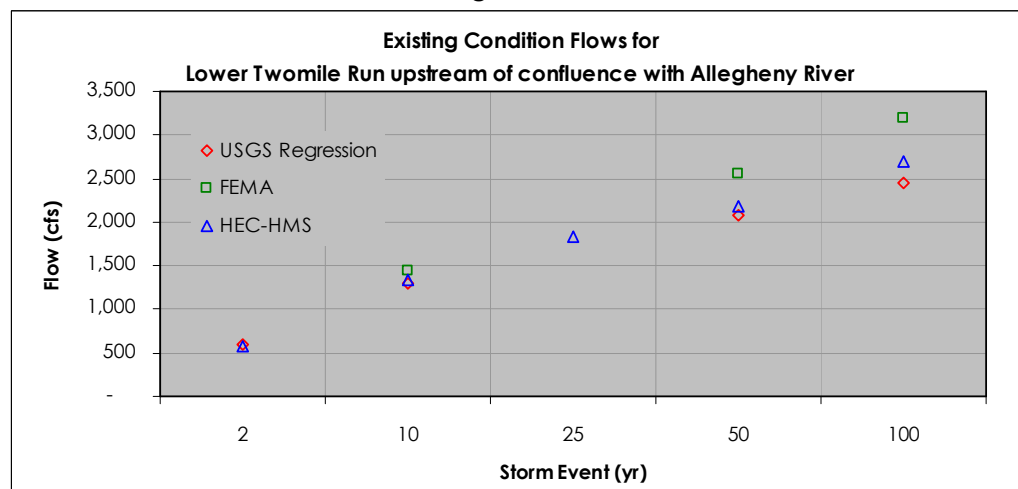


Figure 6.11

Section VI – Technical Analysis – Modeling

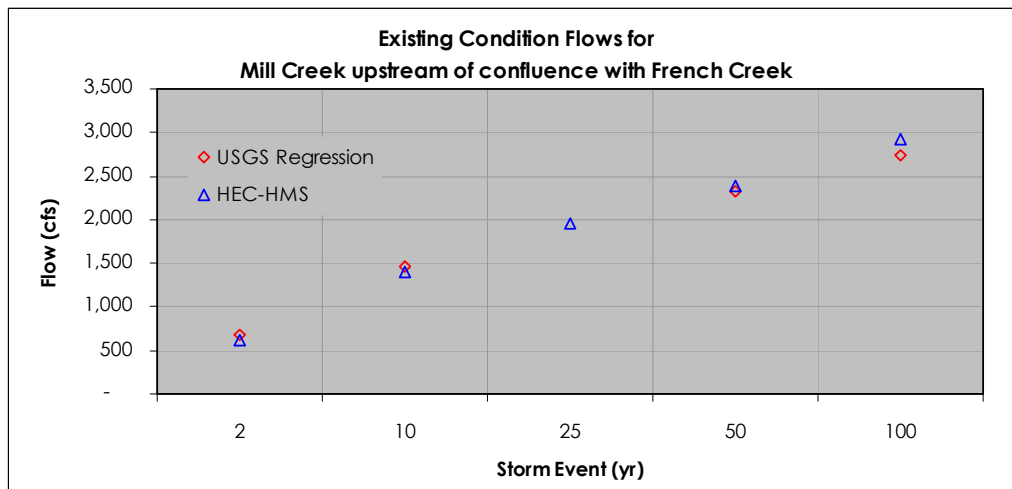


Figure 6.12

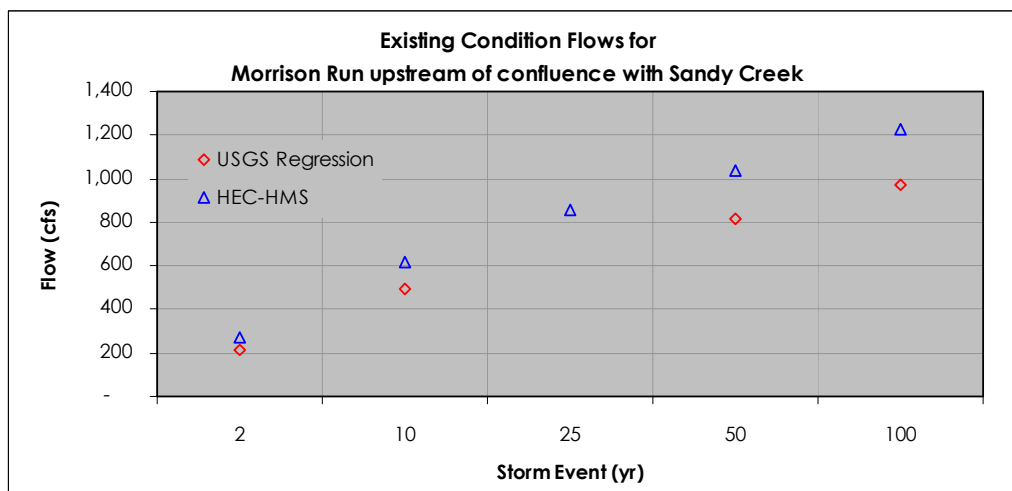


Figure 6.13

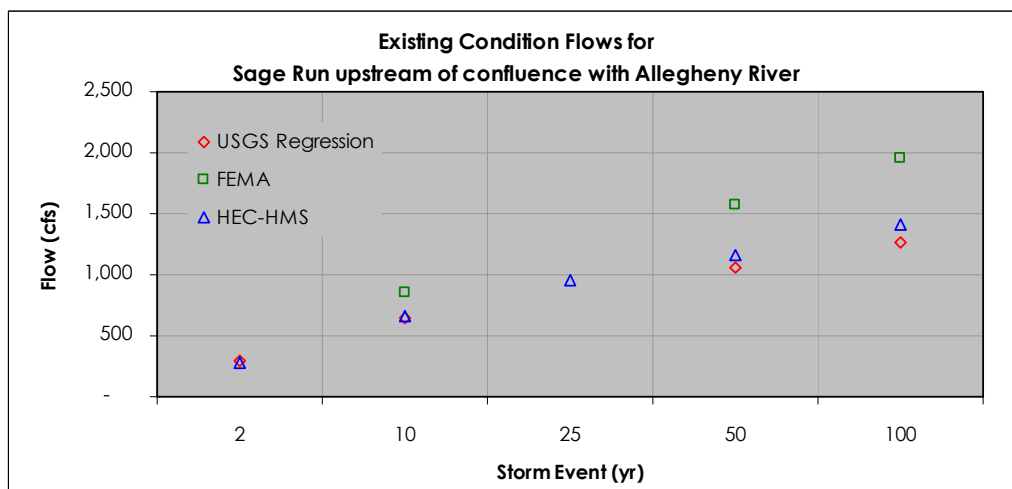


Figure 6.14

Section VI – Technical Analysis – Modeling

MODELING RESULTS

Once the existing conditions model was calibrated and the existing conditions peak flows were established, additional models were developed to assist in determining appropriate stormwater management controls for the watersheds. Based on a comparison of existing and future land use, most subbasins will experience varying degrees of development through the full build-out future condition.

The following simulations were performed with HEC-HMS (2, 10, 25, 50 and 100-year) for Halls Run, Little Sandy Creek, Lower Twomile Run, Mill Creek, Morrison Run, Sage Run, and Venango Tributaries:

Existing Conditions (Ex)

An existing conditions model was developed and analyzed using the calibration procedures described above. Results from the existing conditions model reflect the estimated land uses from 2010. The existing condition flows are provided in Appendix A for both watersheds.

Future Conditions with No Stormwater Controls (F-1)

A future conditions model was developed and analyzed using the projected future land use coverage for the year 2020 provided by Venango County. The revised land use resulted in an increased curve number and a decreased time of concentration for several subbasins. It was assumed that there was no required detention or any other stormwater controls in this simulation.

Future Conditions with Design Storm Method and Release Rates as Stormwater Controls (CG-1R)

A future conditions model with Stormwater Controls was developed by modifying the future conditions model to include the effects of peak rate controls and the volume removal requirements of the Design Storm Method.

The effects of peak rate controls, through detention of post development flows, was estimated by routing the post development flow for each subbasin through a simulated reservoir. The reservoirs were designed so that they could release no more than the pre-development flow estimate. This approach was assumed to simulate the additive effect of all of the individual detention facilities within a sub-basin. The volume removal requirements of the Design Storm Method were simulated using modified initial abstraction values as described above and in Appendix A.

The approach in this Act 167 Plan was to 1) estimate the effects of detention of post development flows and 2) apply release rates to subwatershed wherever there is a significant increases in peak flow at the points of interest. The results for each watershed are presented below; detailed results of the modeling are provided in Appendix A.

MODELED WATERSHEDS WITHIN VENANGO COUNTY

The increases in the modeled watersheds within Venango County are depicted in *Figure 6.15*.

Table 6.4 shows the effects of future condition discharges with no peak rate or volume controls.

Storm Event (year)	Effects of Future Condition on Discharges		
	Maximum % Increase in Future Conditions	Average % Increase in Future Conditions ¹	Portion of subbasins with Increase (%)
2	512.7	32.2	44.0
10	233.0	20.0	44.0
25	185.6	17.4	44.0
50	168.3	16.5	44.0
100	150.8	15.4	44.0

Notes: ¹ Area weighted averages

Table 6.4. Future Condition Flows with No Stormwater Management Controls for Modeled Watersheds within Venango County

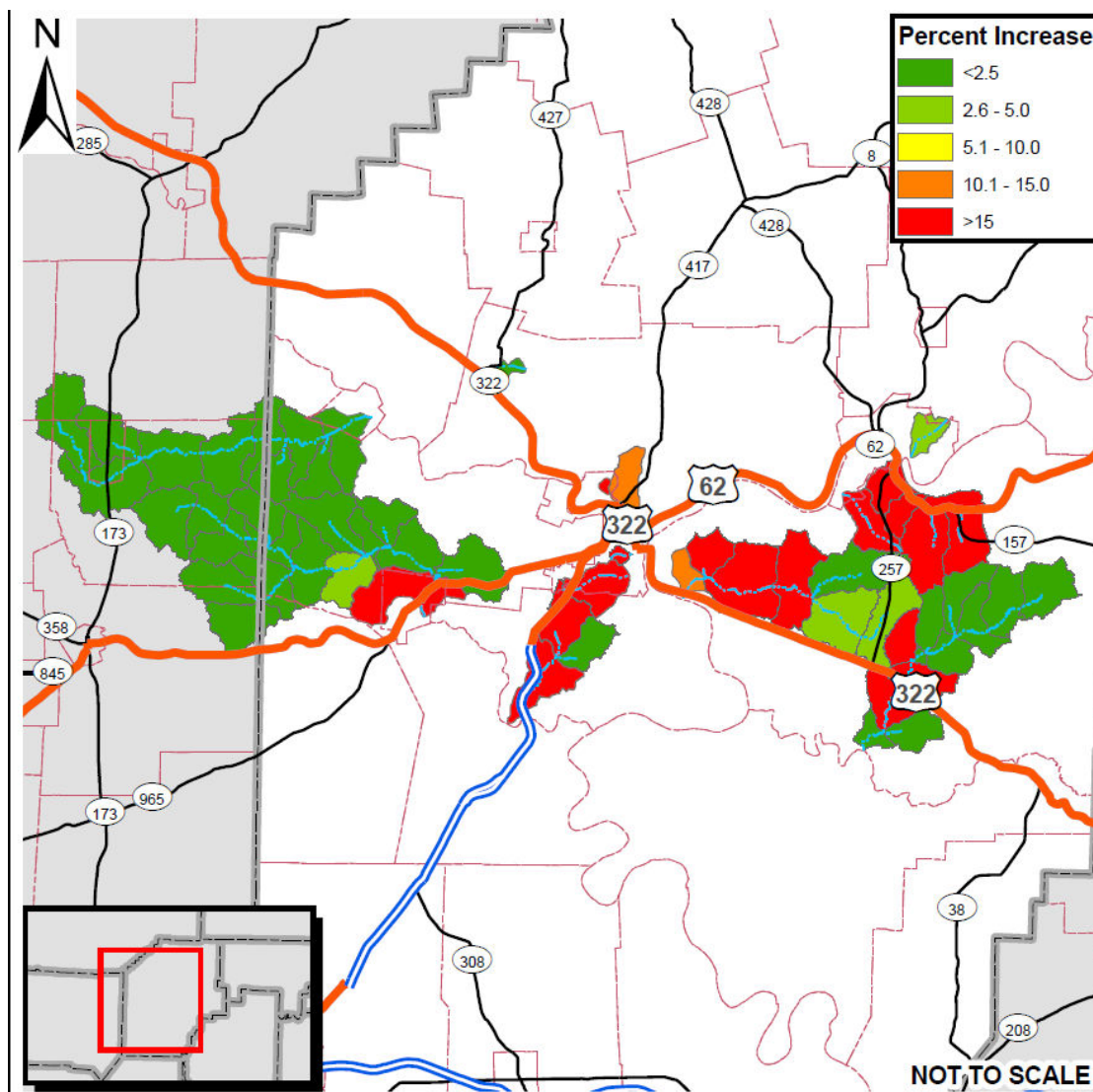


Figure 6.15. Increase in Flow for 2-year Storm Event with No SWM Controls for Modeled Watershed within Venango County

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Table 6.5 shows the reduction in peak flows that would occur if only the Design Storm Method were implemented without any peak rate controls. The flows for the lower magnitude events are substantially reduced compared to future conditions with no stormwater management controls with the implementation of the Design Storm Method. The flows for the higher magnitude events are moderately reduced with implementation of the Design Storm Method, but significant increases still occur.

Storm Event (year)	Effects of CG1 on Discharges		
	Maximum % Increase with CG1	Average % Increase with CG1 ¹	Portion of subbasins with Increase (%)
2	1.1	0.2	24.0
10	24.7	4.0	40.0
25	40.3	5.5	44.0
50	48.0	6.5	42.0
100	54.2	7.1	42.0

Notes: ¹Area weighted averages

Table 6.5 Future Subbasin Flows with Design Storm Method Only – No peak control for Modeled Watersheds within Venango County

If there was a significant increase at a point of interest, the allowable release rate was reduced until the increase in peak flow at the points of interest was reduced to acceptable values. Table 6.6 reflects the range of release rates that are associated with the modeled watersheds within Venango County.

Storm Event (year)	Release Rates with the Design Storm Method
	Release Rates (%) ¹
2	100
10	70-80-90-100
25	70-80-90-100
50	70-80-90-100
100	70-80-90-100

Notes: ¹For the 10, 25, 50, and 100 year storms.

Table 6.6. Release Rates for Modeled Watersheds within Venango County

STORMWATER MANAGEMENT DISTRICTS

When substantial increases are found in the HEC-HMS model due to additive effects of future development, it may be necessary to restrict post development discharges to a fraction of pre-development flow. The fraction has historically ranged between 50 and 100 percent of the pre-development flow in previous Act 167 efforts. A 75% release rate district would indicate that any future development within the district be required to restrict post-development flows to 75% of pre-development flows.

Release rate theory and the designation of stormwater management districts is not substantially supported in stormwater literature. The calculation of release rates is heavily dependent on

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timing and growth projections, both of which involve a high degree of uncertainty. Additionally, it has been observed that localized stormwater measures do not typically capture and detain entire tributary areas (Emerson, 2003). Given these limitations with release rates, the following criteria were examined before applying release rates to the modeled watersheds:

1. Numerous problem areas exist in a pattern that indicate systemic stormwater problems;
2. Historic, repeated flooding has been observed;
3. Future planning projections indicate growth patterns that have historically contributed to documented problems; and
4. Release rates are to be designated on higher order watersheds only; larger downstream areas with well established bed-and-bank streams are not as affected by relatively small scale development and therefore do not benefit from release rates.

When the above criteria indicate a need for additional stormwater management controls, release rates are considered. The results from hydrologic models are used as guidance to establish appropriate release rates. Ultimately, reasonable hydrologic judgment is used in the final designation of release rates.

HALLS RUN

Halls Run was evaluated on the above criteria for implementation of stormwater management districts. The anticipated future development is concentrated in the lowest part of the watershed. In this regard, there would be little benefit to restricting upstream development any more than ensuring that all post-development discharges be limited to pre-development levels. In considering the additional criteria it was determined that stormwater management districts would not be implemented.

LITTLE SANDY CREEK

Little Sandy Creek was evaluated on the above criteria for implementation of stormwater management districts. Part of the Little Sandy Creek watershed is located in Mercer County. The anticipated future development is concentrated in the lowest part of the watershed. In this regard, there would be little benefit to restricting upstream development any more than ensuring that all post-development discharges be limited to pre-development levels. In considering the additional criteria it was determined that stormwater management districts would not be implemented. Stormwater management districts may or may not be desirable in an analysis that considers future growth in Mercer County.

LOWER TWO MILE RUN

Evaluation of the Lower Two Mile Run watershed indicates a need for stormwater management districts. The watershed has had numerous problems areas in patterns indicative of systemic problems. Additionally future growth is projected throughout the watershed. Stormwater management districts have been developed for portions of the watershed with release rates ranging between 70 and 100%.

MILL CREEK

Mill Creek was evaluated on the above criteria for implementation of stormwater management districts. A large percentage of the Mill Creek watershed is in Mercer County and future development is not anticipated within Venango County. In this regard, there would be little

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benefit to restricting upstream development any more than ensuring that all post-development discharges be limited to pre-development levels. In considering the additional criteria it was determined that stormwater management districts would not be implemented. Stormwater management districts may and may not be desirable in an analysis that considers future growth in Mercer County.

MORRISON RUN

Evaluation of the Morrison Run watershed indicates a need for stormwater management districts. The watershed has had numerous problems areas in patterns indicative of systemic problems. Additionally future growth is projected throughout the watershed. Stormwater management districts have been developed for portions of the watershed with release rates ranging between 90 and 100%.

SAGE RUN

Evaluation of the Sage Run watershed indicates a need for stormwater management districts. The watershed has had numerous problems areas in patterns indicative of systemic problems. Additionally future growth is projected throughout the watershed. Stormwater management districts have been developed for portions of the watershed with release rates ranging between 80 and 100%.

VENANGO TRIBUTARIES

The selected tributaries within Venango County were evaluated on the above criteria for implementation of stormwater management districts. It was determined that with the implementation of the Design Storm Method there would be little benefit to restricting development any more than ensuring that all post-development discharges be limited to pre-development levels while implementing the Design Storm Method. In considering the additional criteria it was determined that stormwater management districts would not be implemented.

The location of the stormwater management districts is shown on *Plate 10 – Stormwater Management Districts*, which also identifies the location for potential regional stormwater facilities.

RECOMMENDATIONS

The modeling results discussed in this and previous sections provide technical guidance on provisions that should be included in the model ordinance. The following recommendations follow from the technical analysis and data collection efforts in preparing this Plan.

Curve number and time of concentration methodologies should be restricted to reflect the observed runoff response in the hydrologic models. For storm events greater than the 10-year storm events, the runoff response to NOAA Atlas 14 rainfall in Venango County was lower than standard NRCS methods predict. This has the potential to allow designers to undersize their stormwater facilities and to increase peak discharges for the higher magnitude events. It is recommended for curve number calculations to assume 'good conditions' when using any curve number table, which is consistent with proposed control guidance. It is recommended for time of concentration computations to use the maximum value provided by 1) the TR-55 segmental method and 2) the NRCS Lag Equation.

Implement a volume control policy in addition to a traditional peak rate methodology. The modeling results show a definite reduction in peak discharge in all storm events with the

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implementation of the control guidance criteria. The control guidance criteria will provide a direct benefit with volume reduction and also an indirect benefit of channel protection.

Implement and enforce a flexible yet clearly documented release rate policy for specified watershed. The stormwater management districts are provided on Plate 10. These should be used to determine the allowable post-development peak flow rate. The use of strategically placed regional facilities and watershed-scale conservation, drainage way, and critical recharge area easements should also be considered as an alternative to release rate implementation.

Provide a clear alternative volume-control and peak-rate control strategy for areas with poorly drained soils or areas with geologic restrictions. Venango County has a substantial number of potential limitations to infiltration facilities: fragipans, shallow bedrock, and hydric soils, floodplains, and documented problem areas. Section 7 provides a recommended procedure for sites with these limitations.

PAST WORK COMPLETED BUT NOT INCLUDED IN THE PLAN

Recent stormwater modeling using different methodology was performed in the Chub Run Watershed in 2008/2009. This effort was targeted towards a specific Municipality. This effort was reviewed and briefly considered for inclusion in the work related to this Plan. However, because of the direction provided by the PAC and due to the methodology used, the model was not included into the Plan modeling effort.

It is our opinion that although not included in this Plan, the affected Municipalities may use the Chub Run model at their discretion, if, in the Municipalities opinion, the requirements placed on development in the Chub Run watershed is more restrictive than the County Ordinance and related Plan.

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TECHNICAL STANDARDS FOR STORMWATER MANAGEMENT

The field of stormwater management has evolved rapidly in recent years as additional research has increased our comprehension of how stormwater runoff is interrelated with the rest of our natural environment. Even now this relationship is not completely understood. Stormwater management practices will continue to evolve as additional knowledge becomes available. Effective resource management involves balancing the positive and negative effects of all potential actions. These actions are considered, and the individual management techniques which provide the best known balance are chosen for implementation. The goal of this Plan is to manage stormwater as a valuable resource, and to manage all aspects of this resource as effectively as possible. This Plan contains technical standards that seek to achieve this goal through four different methods. These standards are summarized as follows:



1. **Peak Discharge Rate Standards** – Peak discharge rate standards are implemented primarily to protect areas directly downstream of a given discharge by attenuating peak discharges from large storm events. These standards are also intended to attenuate peak flows throughout the watershed during large storm events. Peak discharge rate controls are applied at individual development sites. Controlling peak discharge rates from the sites entails collection, detention, and discharge of the runoff at a prescribed rate. This is an important standard for achieving stable watersheds.
2. **Volume Control Standards** – The standards in this Plan that address increased stormwater volume are intended to benefit the overall hydrology of the watershed. The increased volume of runoff generated by development is the primary cause of stormwater related problems. Increased on-site runoff volume commonly results in a sustained discharge at the designed peak discharge rate, as well as an increased volume and duration of flows experienced after the peak discharge rate. Permanently removing a portion of the increased volume from a developed site is key in mitigating these problems and maintaining groundwater recharge levels. Meeting this standard generally involves providing and utilizing infiltration capacity at the development site, although alternative methods may be used.
3. **Channel Protection Standards** – Channel protection standards are designed to reduce the erosion potential from stormwater discharges to the channels immediately downstream. Even though peak discharge rate controls are implemented for larger design storms, they do not provide controls for the smaller storms. These storms account for the vast majority of the annual precipitation volume. Past research has shown that channel formation in developed watersheds is largely controlled by these small storm events. The increased volume and rate of stormwater runoff during small storms forces stream channels to change in order to accommodate the increased flows. Channel protection standards will be achieved through implementation of permanent removal of increased volume from discharges during low flow storm events.
4. **Water Quality Standards** – The water quality standards contained in this Plan are meant to provide a level of pollutant removal from runoff prior to discharge to receiving streams.

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Stormwater runoff can deliver a wide range of contaminants to the receiving stream, which leads to a variety of negative impacts. Water quality standards can be achieved through reducing the source of pollutants and utilizing natural and engineered systems that are capable of removing the pollutants.

Beyond the standards discussed above, other measures may be taken to ensure that stormwater is properly managed. Some of these measures are discussed later in *Section X, Additional Recommendations*. These measures are included as recommendations because they are beyond the regulatory scope of this Plan. Municipalities should consider these recommendations seriously.

Stormwater management is an issue that is entwined with land use decisions and has social and economic implications. To maximize the effectiveness of a stormwater management program, a holistic approach is needed. Stormwater management should be a consideration in any ordinance decisions that affect how land is used.

CRITERIA FOR CONTROL OF STORMWATER RUNOFF

The principal purpose of this Plan was to develop criteria for control of stormwater runoff that are specific to the watersheds in Venango County. Mathematical modeling techniques, as discussed in the previous chapter, were used to simulate the existing conditions throughout the county and to determine the effects anticipated future development will have on stormwater runoff within these watersheds. The models were used to determine the outcome of a variety of different stormwater control scenarios. These results were then used to determine a group of control criteria that provides the best results on a watershed wide basis. The outcome of each analysis is stormwater control criteria that are appropriate and applicable to that watershed.

The process of developing unique controls for individual watersheds is complicated by the reality that regulations must be implemented and enforced across varying jurisdictions. The more site specific and complicated a regulatory structure is, the more difficult it becomes to implement the regulations. For this reason it is most advantageous to develop a system of controls that are similar in structure but can also be adjusted as necessary to meet the specific needs of each watershed. The need for balance between these two important concepts has led to the system of stormwater control criteria contained within this Plan.

A broad and uniform approach has been developed for implementation of water quality, volume control, and channel protection controls. These criteria have been developed with adequate latitude in implementation to be applicable to most watersheds statewide. Peak discharge rate control standards, which are unique to each watershed, have been developed to achieve watershed specific controls.

PEAK DISCHARGE RATE CONTROLS

Peak discharge rate controls have been the primary method of implementing stormwater management controls for many years. However, peak rate controls are generally applied to individual sites with little to no consideration given to how the site discharge impacts overall stream flows. It is necessary to consider the cumulative effects of site level peak rate controls, and their contribution to the overall watershed hydrology, in order to control regional peak flows. This is accomplished through mathematical modeling of the watershed. The intent of the modeling is to analyze the flow patterns of the watershed, the impact of development on those patterns, and, if necessary, develop a release rate for various subwatersheds such that the rate of release of the increased volumes of runoff generated is not detrimental to downstream areas.

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In some subbasins, it is necessary to implement strict release rates that require sites to discharge at flows somewhat lower than those calculated for pre-development flows. This is due to the timing of the peak flows from all of the subbasins, and how flows from the subbasin in question impact the overall stream flows. Variable release rates for subbasins throughout a watershed are an important part of achieving regional peak flow controls. The proposed release rates calculate no peak flow increase above the existing condition peak flows at any point throughout the county watersheds. Strict release rates for the more frequent design storms are necessary to meet this criterion in some subwatersheds. The proposed release rates for this Plan fall into two categories:

1. Areas not covered by a Release Rate Map:

Post-development discharge rates shall not exceed the predevelopment discharge rates for the 2-, 10-, 25-, 50-, and 100-year storms. If it is shown that the peak rates of discharge indicated by the post-development analysis are less than or equal to the peak rates of discharge indicated by the pre-development analysis for 2-, 10-, 25-, 50-, and 100-year, 24-hour storms, then the requirements of this section have been met. Otherwise, the applicant shall provide additional controls as necessary to satisfy the peak rate of discharge requirement.

2. Areas covered by a Release Rate Map:

For the 2-, 10-, 25-, 50-, and 100-year storms, the post-development peak discharge rates will follow the applicable approved release rate maps. For any areas not shown on the release rate maps, the post-development discharge rates shall not exceed the predevelopment discharge rates.

VOLUME CONTROLS

Developed sites experience an increased volume of runoff during all precipitation events. The increased volume of stormwater is the cause of several related problems such as increased channel erosion, increased main channel flows, and reduced water available for groundwater recharge. Reducing the total volume of runoff is key in minimizing the impacts of development. Volume reduction can be achieved through reuse, infiltration, transpiration, and evaporation. When infiltration is used as a stormwater management technique, multiple goals are achieved through implementation of a single practice. Infiltrating runoff reduces release rates, reduces release volumes, increases groundwater recharge, and provides a level of water quality improvement. These opportunities will be provided by use of Best Management Practices such as infiltration structures, replacement of pipes with swales, and disconnecting roof drains. Other methods that may be used are decreased impervious cover, maximizing open space, and preservation of soils with high infiltration rates.

The proposed volume controls for this Plan include two pieces:

1. Reduction of runoff generated through utilization of low impact development practices to the maximum extent practicable.
2. Permanent removal of a portion of the runoff volume generated from the total runoff flow.

The permanent removal of runoff volume is to be achieved through one of three available methods:

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1. *The Design Storm Method* (CG-1 in the SWM Manual¹⁾) is applicable to any size of Regulated Activity. This method requires detailed modeling based on site conditions.
 - A. Do not increase the post-development total runoff volume for all storms equal to or less than the 2-year 24-hour duration precipitation.
 - B. For modeling purposes:
 - i) Existing (pre-development) non-forested pervious areas must be considered meadow or its equivalent.
 - ii) Twenty percent of existing impervious area, when present, shall be considered meadow in the model for existing conditions.
2. *The Simplified Method* (CG-2 in the SWM Manual¹⁾) provided below is independent of site conditions and should be used if the Design Storm Method is not followed. This method is not applicable to Regulated Activities greater than one acre or for projects that require design of stormwater storage facilities. For new impervious surfaces:
 - A. Stormwater facilities shall capture at least the first two inches of runoff from all new impervious surfaces.
 - B. At least the first one inch of runoff from new impervious surfaces shall be permanently removed from the runoff flow -- i.e. it shall not be released into the surface waters of this Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.
 - C. Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first one-half inch of the permanently removed runoff should be infiltrated.
 - D. This method is exempt from the requirements of Section 305, Rate Controls.
3. Alternatively, in cases where it is not possible, or desirable, to use infiltration-based best management practices to partially fulfill the volume control requirements the following procedure shall be used:
 - A. The following water quality pollutant load reductions will be required for all disturbed areas within the proposed development:

Pollutant Load	Units	Required Reduction (%)
Total Suspended Solids (TSS)	Pounds	85
Total Phosphorous (TP)	Pounds	85
Total Nitrate (NO ₃)	Pounds	50

- B. The performance criteria for water quality best management practices shall be determined from the *Pennsylvania Stormwater Best Management Practices Manual*, most current version.

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WATER QUALITY CONTROLS

Urban runoff is one of the primary contributors to water pollution in developed areas. The most effective method for controlling non-point source pollution is through reduction, or elimination, of the sources. However, it is not reasonable to assume that all sources of pollution can be reduced or eliminated. For this reason, implementation of natural and engineered systems must be used to achieve the desired results. The water quality control standards will be achieved through the use of various Best Management Practices to reduce the sources of water pollution and treat those that cannot be eliminated.

A combination of source reduction measures through non-structural BMPs and water quality treatment through use of structural BMPs is the proposed water quality control strategy of this Plan. Reducing the amount of runoff to be treated is the preferred strategy to meet this goal:

- Minimize disturbance to floodplains, wetlands, natural slopes over 8%, and existing native vegetation.
- Preserve and maintain trees and woodlands. Maintain or extend riparian buffers and protect existing forested buffer. Provide trees and woodlands adjacent to impervious areas whenever feasible.
- Establish and maintain non-erosive flow conditions in natural flow pathways.
- Minimize soil disturbance and soil compaction. Over disturbed areas, replace topsoil to a minimum depth equal to the original depth or 4 inches, whichever is greater. Use tracked equipment for grading when feasible.
- Disconnect impervious surfaces by directing runoff to pervious areas, wherever possible.

Treating the runoff that cannot be eliminated is the secondary strategy for attaining the water quality standards. By directing runoff through one or more BMPs, runoff will receive some treatment for water quality, thereby reducing the adverse impact of contaminants on the receiving body of water.

CONTROLS FOR ROADWAY PROJECTS

For purposes of Act 167 Stormwater Management Plans (Plans), design policy pertaining to stormwater management facilities for Pennsylvania Department of Transportation (PennDOT), and Pennsylvania Turnpike Commission (PTC) roadways and associated facilities are provided in Sections 13.7 (Antidegradation and Post Construction Stormwater Management Policy) of *PennDOT Publication No. 13M, Design Manual Part 2* (August 2009), as developed, updated, and amended in consultation with PADEP. As stated in DM-2.13.7.D (Act 167 and Municipal Ordinances), PennDOT and PTC roadways and associated facilities shall be consistent with Act 167 Plans. DM-2.13.7.B (Policy on Antidegradation and Post Construction Stormwater Management) was developed as a cooperative effort between PennDOT and PADEP. DM-2.13.7.C (Project Categories) discusses the anticipated impact on the quality, volume, and rate of stormwater runoff.

Where standards in Act 167 Plans are impracticable, PennDOT or PTC may request assistance from DEP, in consultation with the County, to develop an alternative strategy for meeting state water quality requirements and the goals and objectives of the Act 167 Plans.

Municipal roadway projects are regulated by municipal stormwater ordinances but Municipalities are exempt from the requirement to file an Operations and Maintenance (O&M) agreement with themselves. For purposes of this Act 167 Plan, road maintenance activities are regulated under 25 Pa Code Chapter 102.

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RECOMMENDED BEST MANAGEMENT PRACTICES

As previously stated, the preferred strategy for achieving the goals of this plan is to reduce, or eliminate, the sources of non-point source pollution. “The treatment of runoff is not as effective as the removal of runoff needing treatment” (Reese, 2009). This is an important concept, in that the most effective way to reduce the number of stormwater runoff problems is to reduce the amount of runoff generated. There are a wide variety of non-structural practices that are used to reduce the amount of runoff generated and to minimize the potential negative impacts of runoff that is generated. All of these BMPs are intended to minimize the interruption of the natural hydrologic cycle caused by development. The relative effectiveness of each non-structural BMP listed in the *Pennsylvania Stormwater Best Management Practices Manual* in Table 7.1 below. These practices should be used where applicable to decrease the need for less cost effective structural BMPs.

Non-Structural Best Management Practice	Stormwater Functions ¹			
	Peak Rate Control	Volume Reduction	Recharge	Water Quality
Protect Sensitive/Special Value Features	Very High	Very High	Very High	Very High
Protect/Conserve/Enhance Riparian Areas	Low/Med.	Medium	Medium	Very High
Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	Med./High	Low/Med.	Low	Medium
Cluster Uses at Each Site; Build on the Smallest Area Possible	Very High	Very High	Very High	Very High
Concentrate Uses Area-Wide through Smart Growth Practices	Very High	Very High	Very High	Very High
Minimize Total Disturbed Area – Grading	High	High	High	High
Minimize Soil Compaction in Disturbed Areas	High	Very High	Very High	Very High
Re-Vegetate and Re-Forest Disturbed Areas using Native Species	Low/Med.	Low/Med.	Low/Med.	Very High
Reduce Street Imperviousness	Very High	Very High	Very High	Medium
Reduce Parking Imperviousness	Very High	Very High	Very High	High
Rooftop Disconnection	High	High	High	Low
Disconnection from Storm Sewers	High	High	High	Low
Street-sweeping	Low/None	Low/None	Low/None	High

NOTES:

¹ All Stormwater function values from *PA Stormwater BMP Manual*

Table 7.1. Stormwater Functions of Structural Best Management Practices

When non-structural practices are unable to achieve the stormwater standards, it may be necessary to employ structural practices. Generally, structural BMPs are chosen to address specific stormwater functions. Some BMPs are better suited for particular stormwater functions than others. The relative effectiveness of structural BMPs at addressing individual stormwater functions varies, as shown in Table 7.2. This table contains all of the structural BMPs listed in the *Pennsylvania Stormwater Best Management Practices Manual* and their stated effectiveness for each stormwater function. Additional information on each practice can be found in the *Pennsylvania Stormwater Best Management Practices Manual*.

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Structural Best Management Practice	Stormwater Functions ¹			
	Peak Rate Control	Volume Reduction	Recharge	Water Quality
Porous Pavement with Infiltration Bed	Medium	Medium	Medium	Medium
Infiltration Basin	Med./High	High	High	High
Subsurface Infiltration Bed	Med./High	High	High	High
Infiltration Trench	Medium	Medium	High	High
Rain Garden / Bioretention	Low/Med.	Medium	Med./High	Med./High
Dry Well / Seepage Pit	Medium	Medium	High	Medium
Constructed Filter	Low-High ²	Low-High ²	Low-High ²	High
Vegetated Swale	Med./High	Low/Med.	Low/Med.	Med./High
Vegetated Filter Strip	Low	Low/Med.	Low/Med.	High
Infiltration Berm and Retentive Grading	Medium	Low/Med.	Low	Med./High
Vegetated Roof	Low	Med./High	None	Medium
Rooftop Runoff - Capture and Reuse	Low	Med./High	Low	Medium
Constructed Wetland	High	Low	Low	High
Wet Pond / Retention Basin	High	Low	Low	Medium
Dry Extended Detention Basin	High	Low	None	Low
Water Quality Filter	None	None	None	Medium
Riparian Buffer Restoration	Low/Med.	Medium	Medium	Med./High
Landscape Restoration	Low/Med.	Low/Med.	Low/Med.	Very High
Soils Amendment and Restoration	Medium	Low/Med.	Low/Med.	Medium

NOTES:

¹ All Stormwater function values from *PA Stormwater BMP Manual*

² Depends on if infiltration is used

Table 7.2. Stormwater Functions of Structural Best Management Practices

The table above shows the qualitative effect of individual BMPs when used as stand alone treatment practices. The overall effectiveness of a stormwater system can be improved when several, smaller BMPs are dispersed throughout a given site. The combination of different BMPs enables each BMP to complement each other by providing a particular stormwater function then allowing the runoff to pass downstream to another BMP that is used to address different criteria. This allows designers to better mimic the site's existing hydrologic features, which are not typically isolated to one area of the site. The "treatment train" system of utilizing multiple BMPs on a single site is an effective technique that, in some cases, may be used to meet all of the stormwater criteria.

Several of the structural BMPs are particularly effective at achieving the criteria for control of stormwater presented in this Plan. The following practices should be considered where appropriate:

RAIN GARDENS

A rain garden, also referred to bioretention, is an excavated shallow surface depression planted with native, water-resistant, drought and salt tolerant plants with high pollutant removal potential that is used to capture and treat stormwater runoff. Rain gardens treat stormwater by collecting and pooling water on the surface and allowing filtering and settling of suspended solids and sediment prior to infiltrating the water. Rain gardens are generally constructed to provide 12 inches or less of ponding depth with shallow side slopes (3:1 max). They are designed to reduce runoff volume, filter pollutants and sediments through the plant material and soil particles,

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promote groundwater recharge through infiltration, reduce stormwater temperature impacts, and enhance evapotranspiration. Their versatility has proved extremely successful in most applications including urban and suburban areas (Pennsylvania Stormwater Best Management Practices Manual, 2006).

Construction of rain gardens varies depending on site specific conditions. However, they all contain the same general components: appropriate native vegetation, a layer of high organic content mulch, a layer of planting soil, and an overflow structure. Often times, an infiltration bed is added under the planting soil to provide additional storage and infiltration volume. Also, perforated pipe can be installed under the rain garden to collect water that has filtered through the soil matrix and convey it to other stormwater facilities. Rain gardens can be integrated into a site with a high degree of flexibility and can be used in coordination with a variety of other structural best management practices. They can also enhance the aesthetic value of a site through the selection of appropriate native vegetation.

DRY WELL/ROOF SUMP

A dry well, sometime referred to as a roof sump, is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of structures. Roof runoff is generally considered "clean" runoff, meaning that it contains few or no pollutants. However, roofs are one of the primary sources of increased runoff volume from developed areas. This runoff is ideal for infiltration and replenishment of groundwater sources due to the relatively low concentration of pollutants. By decreasing the volume of stormwater runoff, dry wells can also reduce runoff rate thereby improving water quality.

Roof drains are connected directly into the dry well, which can be an excavated pit filled with uniformly graded aggregate wrapped in geotextile or a prefabricated storage chamber. Runoff is collected during rain events and slowly infiltrated into the surrounding soils. An overflow mechanism such as an overflow outlet pipe, or connection to an additional infiltration area, is provided as a safety measure in the event that the facility is overwhelmed by extreme storm events or other surcharges (Pennsylvania Stormwater Best Management Practices Manual, 2006). Dry wells are not recommended within a specified distance to structures or subsurface sewage disposal systems.

VEGETATED SWALES

Vegetated swales are broad, shallow channels, densely planted with a diverse selection of native, close-growing, water-resistant, drought and salt tolerant plants with high pollutant removal potential. Plant selection can include grasses, shrubs, or even trees. These swales are designed to slow runoff, promote infiltration, and filter pollutants and sediments while conveying runoff to additional stormwater management facilities. Swales can be trapezoidal or parabolic, but should have broad bottoms, shallow side slopes (3:1 to 5:1 ratio), and relatively flat longitudinal slopes (1-6%). Check-dams can be utilized on steeper slopes to reduce flow velocities. Check-dams can also provide limited detention storage and increase infiltration volume. Vegetated swales provide many benefits over conventional curb and gutter conveyance systems. They reduce flow velocities, provide some flow attenuation, provide increased opportunity for infiltration, and providing some level of pretreatment by removing sediment, nutrients and other pollutants from runoff. A key feature of vegetated swales is that they can be integrated into the landscape character of the surrounding area. They can often enhance the aesthetic value of a site through the selection of appropriate native vegetation.

A vegetated swale typically consists of a band of dense vegetation, underlain by at least 24 inches of permeable soil. Swales constructed with an underlying 12 to 24 inch aggregate layer provide significant volume reduction and reduce the stormwater conveyance rate. The

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permeable soil media should have a minimum infiltration rate of 0.5 inches per hour and contain a high level of organic material to enhance pollutant removal. A nonwoven geotextile should completely wrap the aggregate trench (Pennsylvania Stormwater Best Management Practices Manual, 2006). There are several variations of the vegetated swale that include installing perforated pipe under the swale to collect water that has filtered through the soil matrix and convey it to other stormwater facilities or combining the swale with an infiltration bed to provide additional infiltration volume.

INFILTRATION FACILITIES

Subsurface infiltration beds are created by placing storage facilities below the proposed surface grade that collects stormwater and provides temporary storage and allows water to slowly infiltrate. Infiltration facilities are designed to provide significant volume reduction through temporary storage and infiltration, which also benefits peak rate control and water quality. Subsurface beds are ideally suited for expansive, generally flat open spaces, such as lawns, playfields, and other recreational areas (PA DEP, 2006). These systems are also well suited for cold climates as they can function year-round if constructed below the frost line.

An infiltration bed usually consists of a layer of highly pervious planting soil and vegetation, underlain by a storage facility. Storage can be provided by an excavated pit filled with uniformly graded aggregate wrapped in geotextile or a prefabricated storage chamber. An overflow structure should be included to provide protection in case of extreme storm events or system failure. Additionally, inspection ports are often added to ease monitoring and maintenance. The bottom of the infiltration bed must be level and distribution systems must be added to larger facilities to ensure that water is infiltrated evenly over the entire surface area. The soil layer and vegetation provide water quality through filtration and increase evapotranspiration. A popular variation of this facility is an infiltration trench, which is the same concept applied as a linear facility. Infiltration trenches are often more shallow than infiltration beds and are designed for smaller flows than infiltration beds. These facilities provide groundwater recharge while also preserving or creating valuable open space and recreation areas.

IMPLEMENTATION OF STORMWATER MANAGEMENT CONTROLS

From a regulatory perspective, the standards and criteria developed in this Plan will be implemented through municipal adoption of the Model Stormwater Management Ordinance developed as part of the Plan. The Model Ordinance contains provisions to realize the standards and criteria outlined in this section. Providing uniform stormwater management standards throughout the county is one of the stated goals of this Plan. This goal will be achieved through adoption of the Model Ordinance by all of the municipalities in Venango County.

From the pragmatic development viewpoint, the stormwater management controls will be put into practice through use of comprehensive stormwater management site planning and various stormwater BMPs. Site designs that integrate a combination of source reducing non-structural BMPs and runoff control structural BMPs will be able to achieve the proposed standards. A design example has been included in *Section VIII* and *Appendix B* to demonstrate how to incorporate the various aspects of the Model Ordinance into the stormwater management design process.

Section VIII – Economic Impact of Stormwater Management Planning

IMPLEMENTATION OF STORMWATER STANDARDS

The economic impact of managing urban stormwater runoff is a major concern. For example, the U.S. EPA has estimated the costs of controlling combined sewer overflows (CSO) throughout the U.S. at approximately \$56 billion (MacMullan and Reich, 2007). Developing and implementing stormwater management programs and urban-runoff controls will cost an additional \$11 to \$22 billion (Kloss and Calarusse, 2006). There are direct economic impacts associated with implementation of stormwater management regulations, regardless of the type of stormwater control standards that are proposed. The design example provided in this section has been developed to highlight a site design approach that can reduce the costs of employing the proposed stormwater management control measures and, at the same time, maximize the benefits which they are intended to provide. The design example is then compared to a similar site design that uses traditional peak rate stormwater controls in order to provide an illustration of the direct economic impact of the proposed regulations using initial construction costs.

Site planning that integrates comprehensive stormwater management into the development process from the initial stages often results in efficiencies and cost savings. Examples of efficiencies include reduction in area necessary for traditional detention basins, less redesign to retrofit water quality and infiltration measures into a plan, and reduced costs for site grading and preparation. Planning for stormwater management early in the development process may decrease the size and cost of structural solutions since non-structural alternatives are more feasible early in the process. In the vast majority of cases, the U.S. EPA has found that implementing well-chosen LID practices, like the proposed stormwater management methods, saves money for developers, property owners, and communities while protecting and restoring water quality (EPA, 2007).

DESIGN EXAMPLE 1

The following design example illustrates the methods used to design stormwater management facilities and structural BMPs in accordance with the volume and peak rate control strategies developed within this Plan. The design process encouraged by the *Pennsylvania Stormwater BMP Manual* is used to determine non-structural BMP credits and perform the calculations necessary to determine if the requirements of the *Model Ordinance* have been met. The 2-year design storm is utilized to illustrate the methods used to meet the volume requirements of the Ordinance. The SCS Runoff Curve Number Method is used for runoff volume calculations as suggested by the *Pennsylvania Stormwater BMP Manual* (2006). Refer to this document for additional guidance, rules and limitations applicable to these methods, and the design of structural and non-structural BMPs.

For the following example, Low Impact Design techniques are utilized to address the volume control and rate control requirements of the *Model Ordinance*. The example addresses these requirements for the entire development, not any single lot, thereby superseding the requirements of the *Small Project Stormwater Management Application*.



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PRE-DEVELOPMENT CONDITIONS

The design example is a 10-lot single family residential subdivision on an 8.1 acre parcel with a total drainage area of 9.78 acres. The existing land use is partially wooded (2.29 acres) with a fallow agricultural field covering the remaining acreage. The entire site is tributary to Mill Run, which flows near the back of the property. All on-site soils are classified in hydrologic soil group B.

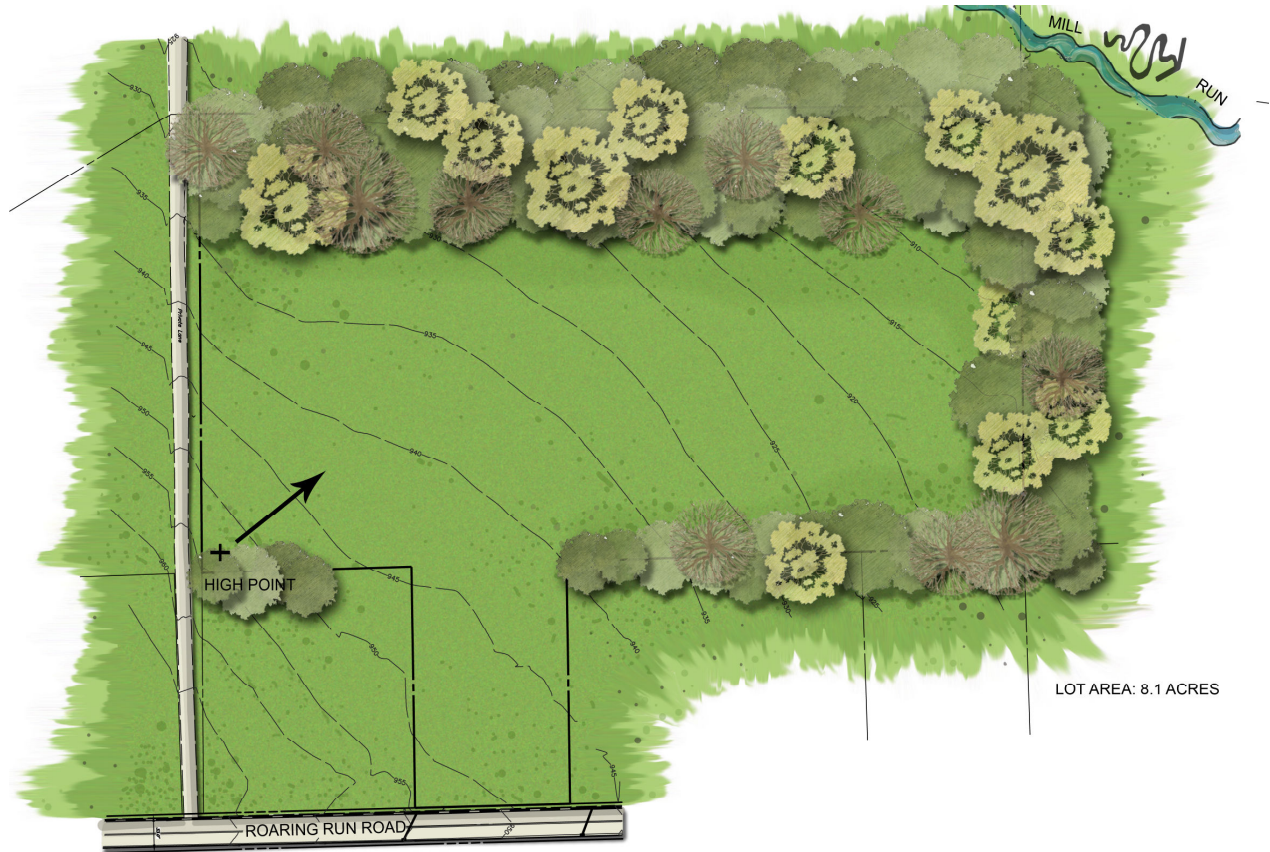


Figure 8.1. Design Example 1 – Pre-Development Conditions

Watershed:	Mill Run
Total Drainage Area:	9.78 acres
Existing Land Use:	Meadow = 7.49 acres
	Woods = 2.29 acres
Hydrologic Soil Group:	'B' – Entire Site
Parcel Size:	8.1 acres
On-Site Sensitive Natural Resources:	Woods (2.18 acres)
	Meadow = 7.12 acres
Pre-Development Drainage Area:	Woods = 0.98 acres
	Total = 8.10 acres

Table 8.1. Pre-Development Data

POST-DEVELOPMENT CONDITIONS

All of the lots will be accessed by a single cul-de-sac road to be constructed for the subdivision. Each house has an assumed 2,150-sf impervious footprint. Various low impact design techniques

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were used in the site design. A large portion of the existing woodlands (1.31 acres) was preserved during construction and will remain wooded through a permanent easement on lots 6-9, the back portion of lots 9-10 were protected from compaction during construction and will remain protected through an easement, roof drains are disconnected from the storm sewer system and directed to dry wells, and rain gardens will be installed on each lot. Runoff from the roadway is collected by swales and conveyed to a bioretention area.



Figure 8.2. Design Example 1 – Post-Development Conditions

Proposed Land Use:	Meadow = 1.61 acres
	Woods = 1.32 acre
	Open Space = 5.43 acres
	Impervious = 1.13 acres
	Ponds as Impervious = 0.31 acres
Protected Sensitive Natural Resources:	Woods (1.31 acre)
Other Protected Areas:	Minimum Disturbance (0.37 acre)
Post-Development Drainage Area:	SWM Area = 7.74 acres
	Undetained = 0.36 acres
	Total = 8.10 acres
Proposed Lot Impervious Areas:	2,150 ft ² / house
	1,000 ft ² / lot

Table 8.2. Post-Development Data

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DESIGN PROCESS FOR VOLUME CONTROLS

The following is a summary of the design process used for implementation of the volume control and rate control requirements of the *Model Ordinance*. This is an outline of the sequence of steps that are used to implement the *Design Storm Method* through a combination of Non-Structural BMP Credits and Structural BMPs that remove volume through infiltration. Detailed calculations and example Worksheets are provided in *Appendix B* for additional clarification of the design process.

Step 1

The first task of the design process is to gather the pertinent site information as it relates to stormwater management. This general information determines which Ordinance provisions are applicable to the stormwater management design for the project. *Worksheet 1* is used for this task.

Step 2

The next step is to determine the sensitive natural resources that are present on the site. *Worksheet 2* is used to inventory these resources. These areas should be considered as the site layout is determined, and should be protected to the maximum extent practicable.

Step 3

As the site layout is being completed, thought should be given to which non-structural BMPs are appropriate for the site in order to reduce the need for stormwater management through structural BMPs. Once the site layout has been finalized and non-structural BMPs have been determined, the designer can begin the stormwater management calculations. The first calculation is to determine the "Stormwater Management Area". This is the land area which must be evaluated for volume of runoff in both pre-development and post-development conditions. Sensitive natural resources that have been protected are not used in the ensuing pre or post-development volume calculations, just as one would not incorporate offsite areas into volume calculations. The top of *Worksheet 3* shows this information. In the example, the acre of protected woodland is removed from the Stormwater Management Area. This will reduce cost by reducing the total volume needed in the peak-rate management facility.

Step 4

The next step is to calculate the volume "credits" for the non-structural BMPs that have been incorporated into the design. This reduces the total volume that is required to be infiltrated by structural BMPs. There are three practices used in the example, a meadow area and a lawn area have been protected from soil compaction and roof drains have been disconnected from the storm sewer system. The areas protected from compaction facilitate higher infiltration rates and disconnecting the roof leaders for the storm sewer system allows infiltration of some stormwater as it flows across the pervious surface. These calculations are completed on *Worksheet 3*.

The total non-structural credits are limited to 25% of the total required infiltration volume. This does not limit the amount of practices that can be implemented, only the amount of credit that can be used to reduce the total required infiltration volume. The total credits calculated must be checked to ensure the 25% threshold has not been exceeded.

Step 5

Worksheet 4 is completed to calculate the difference in the 2-year design storm runoff volume from pre-development conditions to post-development conditions. The 2-year

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volume increase, minus the volume credits for non-structural BMPs, represents the volume that must be managed through structural BMPs.

Step 6

Determine the type of structural BMPs that may be appropriate for the site and decide which practices will be used. Use *Worksheet 5.A* to calculate the volume of water that will be infiltrated by each BMP. Then, *Worksheet 5* is used to summarize the volume that will be infiltrated through structural practices. If the total structural volume is greater than (or equal to) the required volume, the volume control requirements of the *Model Ordinance* have been met.

Summary of Results

The design process outlined above was followed to design the facilities necessary to meet the volume control and peak rate control requirements of the *Model Ordinance*. The total required permanently removed volume is 12,599 ft³. A summary of the results for Design Example 1 is provided in the table below:

Description of Stormwater Best Management Practice	Size (ft ³)	Volume Credit (ft ³)
Minimum Soil Compaction	16,200	337
Disconnect Non-Roof Impervious to Vegetated Areas	10,000	278
Total Non-Structural Volume:		615
On-Lot Rain Gardens (10)	6,740	5,049
On-Lot Dry Wells (10)	4,400	5,787
Bioretention	5,175	3,778
Total Structural Volume:		14,613
Total Volume Removed:		15,228

Table 8.3. Summary of BMP Credits

DESIGN OF PEAK RATE CONTROLS

In this example, additional stormwater control facilities are necessary to manage the increase in peak rate flows that would otherwise result from the development activities. Peak rate control facilities are designed to reduce post-development peak flows to, or below, pre-development peak flows. In release rate districts, post-development flows are further reduced to a given percentage of the pre-development peak flows. Design of peak rate controls necessitates flood routing, for which a flood hydrograph is required (PennDOT, 2008). A suitable hydrologic method is needed to generate runoff hydrographs for flood routing.

The Rational Equation (i.e., $Q = C \times I \times A$) was originally developed to estimate peak runoff flows. The Modified Rational Method is an adaptation of the Rational Method which is used to estimate runoff hydrographs and volumes. While, this method is useful for estimating peak flows from relatively small, highly developed drainage areas, various sources document the shortcomings of this method in developing hydrographs and estimating volume (PennDOT, 2008, DEP 2006). For this reason, use of the Rational Method is strongly discouraged for the volume-sensitive routing calculations necessary for design detention facilities and outlet controls.

The SCS Unit Hydrograph Method was developed to be used in conjunction with the Curve Number Runoff Method of generating runoff depths to estimate peak runoff rates and runoff hydrographs. While these methods have numerous limitations, the principal application of this

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method is in estimating runoff volume in flood hydrographs, or in relation to flood peak rates (NRCS, 2008). Therefore, the NRCS Rainfall-Runoff Method (i.e. using the Curve Number Runoff Method and SCS Unit Hydrograph Method together to produce rainfall-runoff response estimates) is the preferred method to calculate runoff peak rates and for rate control facility design calculations.

Various computer software programs are available for modeling rainfall-runoff simulations to perform peak rate control analyses for development projects. Most of the available computer modeling software is based on the NRCS Rainfall-Runoff Method. These models include the U.S. Army Corps of Engineers' Hydrologic Modeling System (HEC-HMS), SCS/NRCS Technical Release No. 20: Computer Program for Project Formulation Hydrology (TR-20) and Technical Release 55 (TR-55), NRCS National Engineering Handbook 650, Engineering Field Handbook, Chapter 2 (EFH2), and U.S. Environmental Protection Agency's Storm Water Management Model (SWMM). These modeling packages are further described in the *Pennsylvania Stormwater BMP Manual* (2006). There are also a variety of other commercially available software packages that complete many of the same functions. Designers should be careful when determining which software should be used to model a particular project to ensure that appropriate methods are being used (i.e., review the modeling method restrictions contained in the *Model Ordinance*).

DESIGN PROCESS FOR PEAK RATE CONTROLS

The peak rate analysis is carried out by completing a comparison of the post-development runoff peak rate to the pre-development runoff peak rate to determine if the rate controls of the *Model Ordinance* have been satisfied. Additional stormwater facilities, such as a detention basin and outlet structure, may be necessary to reduce post-development peak flow rates to the required peak flow rates. The volume of runoff removed by BMPs should be removed from the total runoff volume when completing peak rate calculations. This is necessary in order to size peak rate control facilities appropriately.

Step 1

The first step is to delineate the pre-development drainage area. This area should include all areas that will be tributary to any proposed stormwater facilities, including any off-site area. Any areas on site that have no proposed land-use changes, and are not tributary to the proposed stormwater facilities, can be removed from the drainage areas. Once the drainage area has been delineated, determine the soil-cover complex and the corresponding curve number for each subarea. If the drainage area contains multiple soil-cover complexes, the designer must determine the appropriate runoff estimation method. (A comparison of the two most prevalent methods is covered in *Appendix B*).

Step 2

The next step is to determine a time of concentration for the pre-development drainage area(s). The *Model Ordinance* requires use of the NRCS Lag Equation for all pre-development time of concentration calculations unless another method is pre-approved by the Municipal Engineer. The average watershed land slope of the pre-development drainage area(s) must be calculated for use in the Lag Equation.

Step 3

Use the information from the previous two steps to calculate the pre-development peak runoff rates for each design storm. Use design storm rainfall depths from NOAA Atlas 14 specific to the area of interest, or the values provided in the *Model Ordinance*. Any appropriate method of estimating peak runoff rates and runoff hydrographs can be used; however use of hydrologic modeling software is the most common method.

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Step 4

Delineate the post-development drainage area(s) and any sub-areas. Post-development sites generally have several drainage sub-areas with multiple soil-cover complex groups in each subarea. The designer must determine a suitable level of detail to be included in the post-development model based on the site design and site conditions. The runoff estimation method chosen for multiple soil-cover complexes should be appropriate for the level of detail that is modeled.

Step 5

Determine time of concentration values for the post-development drainage area(s). The NRCS Segmental Method is the preferred method for all post-development time of concentration calculations. The Segmental Method is used to calculate travel times for individual segments of sheet flow, shallow concentrated flow, and open channel flow which are summed to calculate the time of concentration. The *Model Ordinance* allows the NRCS Lag Equation to be used for residential, cluster, or other low impact designs less than or equal to 20% impervious area.

Step 6

Use the information from the previous two steps and relevant stormwater facility information (e.g. BMP size and outlet configuration, detention facility stage-discharge data, etc.) to calculate the post-development peak runoff rates for each design storm. This is most often done by using hydrologic modeling software to develop a model of the post-development site which is used to estimate peak runoff rates and runoff hydrographs.

The hydrologic model is used to finalize the design of the peak rate control facilities such as the detention basin and the outlet control structure. Steps 4-6 must be revisited whenever additional BMPs are added, or moved, or any change to the site design alters drainage areas.

Summary of Results

For this example, the peak rate control analysis was completed with hydrologic modeling software that is based on TR-20 modeling procedures. Every component of the stormwater design (including each structural BMP) was included in the model. This helped account for peak flow attenuation and permanent volume removal that was provided by the BMPs. The runoff volume removed by the BMPs was removed from the total runoff volume by using an option within the software. A detention basin providing 8,600 ft³ of storage (plus the required freeboard depth) and associated outlet controls were necessary to reduce the 100-year post-development peak rate flows to the pre-development flow rate. If the effects of the individual BMPs had been ignored in the post-development model, the design would have needed a basin that provided 23,850 ft³ of storage (plus the required freeboard depth) to achieve the required flow reduction for the 100-year storm. As shown in Table 8.4 the peak rate control requirements of the *Model Ordinance* have been achieved.

	Design Storm					
	1-year	2-year	10-year	25-year	50-year	100-year
Pre-Development	0.1	0.6	4.1	7.6	11.1	15.3
Post-Development with No SWM	2.5	5.2	14.5	21.9	28.8	36.6
Post-Development	0.1	0.4	4.1	7.4	10.6	15.3

Table 8.4. Summary of Peak Rate Flows

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ECONOMIC IMPACT OF STORMWATER MANAGEMENT STANDARDS

Stormwater management standards are necessary to mitigate the adverse affects of increased stormwater runoff from developing areas. Implementation of these standards comes at a cost to regulators and developers alike. However, these costs are only a fraction of the costs associated with mitigating mis-managed or un-managed runoff. Since activities within a watershed do not always exhibit a direct and measurable cause and effect relationship, identifying some of the costs associated with stormwater management can be difficult and somewhat subjective. It can be similarly difficult to quantify certain costs and altogether impossible to assign an economic value to outcomes such as environmental benefits.

There are three principal methods available to assess the economics of implementing the proposed stormwater management regulations:

1. Cost Comparison – This is the most basic type of analysis. It is completed by comparing initial construction costs and other direct costs such as land value. This type of analysis is incomplete in scope in that it does not capture the benefits of improved stormwater management or variances in life-cycle costs such as operation and maintenance and life expectancy.
2. Life-Cycle Cost Analysis – A life-cycle cost analysis includes all costs throughout the projects period of service. This includes planning, design, installation, operation and maintenance and life expectancy. A life-cycle analysis gives a more complete financial comparison than a cost comparison, but again excludes the environmental and other benefits of improved stormwater management.
3. Cost-Benefit Analysis – This is the most thorough method of analysis and considers the full range of costs and benefits for each alternative. A cost-benefit analysis considers the same project costs as a life-cycle analysis, but includes the environmental and other benefits of improved stormwater management practices in the assessment. This method of analysis is very difficult because it requires valuation of costs and benefits which are not easily measured in monetary terms (i.e. environmental goods and services such as clean air, reduced erosion, or improved aquatic habitat). It is difficult to quantify the value of these non-market goods and services.

The amount of information required to perform a life-cycle cost or cost-benefit analysis makes use of these two methods impractical for this discussion. These methods are also complicated by the fact that costs and benefits are often realized by different parties. As an example, a developer/owner pays for initial construction costs, the owner can benefit from potential life-cycle cost savings, and the general public benefits from potential environmental benefits such as improved water quality. The flexibility, availability of data, and simplicity of cost comparisons make this the most commonly used method of comparison. A cost comparison will give a relatively accurate representation of the economic impact of the initial cost of implementing the proposed stormwater management controls.

A cost comparison has been completed for two conceptual stormwater management designs to provide an example of the direct costs associated with implementation of the standards contained within this Plan. The stormwater designs are based on the site used in the Design Example. The site layout is similar for both designs to reduce the number of variables. The first plan was designed to meet traditional peak-rate stormwater management standards of reducing the post-development peak flow rates to those present in pre-development conditions for all design storms. The second plan follows the design procedures found in this Plan and meets the volume control requirements of the *Model Ordinance*.

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TRADITIONAL SUBDIVISION LAYOUT WITH PEAK RATE CONTROL DESIGN

The layout for this example is typical of conventional subdivision designs. All of the existing woodlands were converted to lawns and no measures were taken to reduce impervious area (e.g. front yard setbacks were not reduced to decrease driveway lengths). The roadway has a 24' cartway with concrete curbs, and there is a sidewalk on one side of the street. The traditional cul-de-sac is entirely paved. The stormwater design utilizes a conventional stormwater collection and conveyance system that uses the concrete curb to direct runoff toward inlets, and an HDPE pipe network carries runoff to a detention basin which is located at the low point on the property. A swale is placed near the downstream edge of the property to collect runoff that is not tributary to the storm sewer network and convey it to the detention basin. In the detention basin, a concrete outlet structure is designed to reduce peak flow rates before discharging to an outlet pipe. A rock rip-rap apron energy dissipater is installed at the pipe outfall.

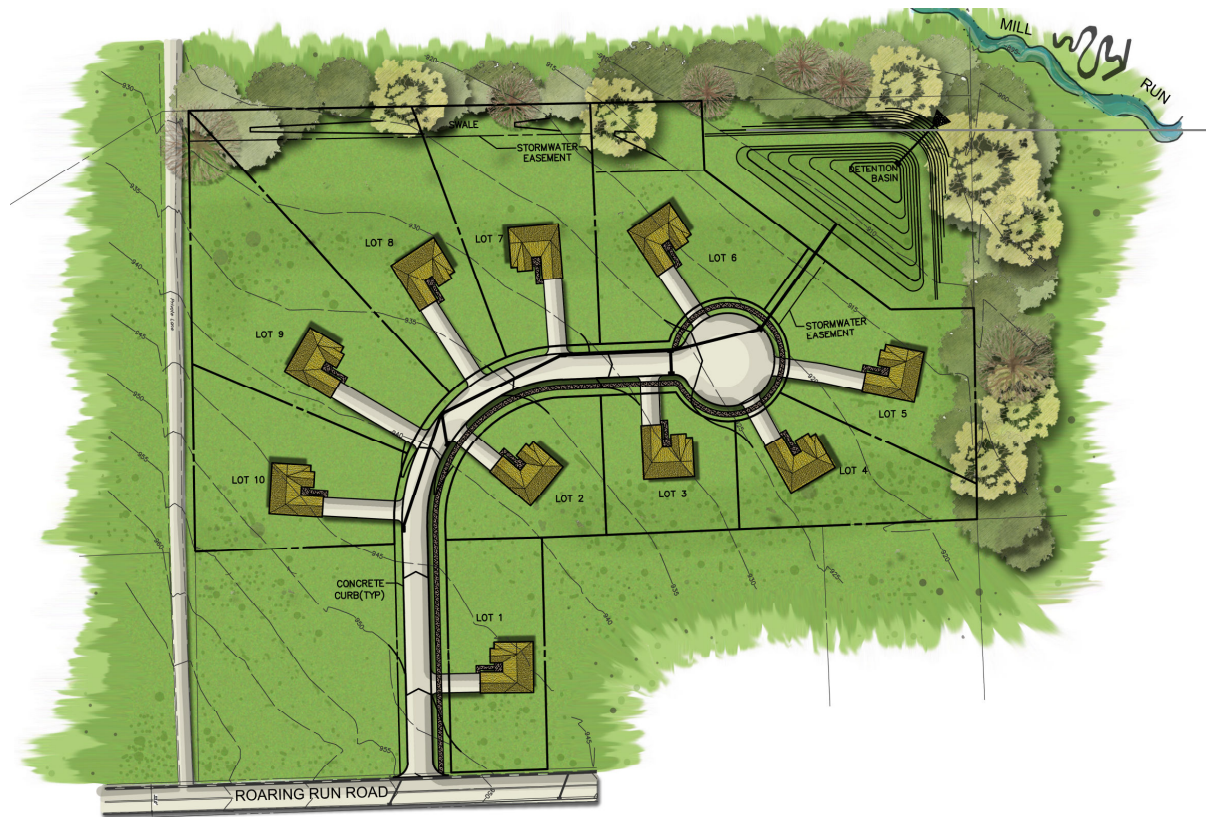


Figure 8.3. Traditional Subdivision Layout (Designed for Peak Rate Control)

LID SUBDIVISION LAYOUT WITH VOLUME CONTROL DESIGN

This design is the post-construction layout that was presented in the Design Example (see Figure 8.2). Several LID techniques were used to reduce runoff. This includes reducing impervious area, preserving existing woodlands where possible, and protecting areas from soil compaction. The roadway is reduced to an 18' cartway with 3' gravel shoulders and swales are employed to collect and convey roadway runoff. Roof runoff is directed to dry wells on each lot, rain gardens are installed on each lot to collect the runoff from on-lot impervious areas as well as part of the lawn runoff. A larger bioretention facility is used to treat runoff from common areas such as the roadway and remove additional runoff volume. A detention basin and concrete outlet structure is used to control the peak discharge rates. A level spreader installed at the end of the outfall serves as an energy dissipater and distributes flow.

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COST COMPARISON

A cost comparison was completed for the two designs described above. This comparison consists of two components: 1) initial construction costs for the developer, and 2) land value in the form of sale price. Construction costs were calculated for only the design elements which differ between the two examples (i.e. earthwork, paving, and stormwater management facilities). Other construction costs were considered to be similar for both layouts and were omitted from the analysis. An itemized estimate of the initial construction cost is included in Appendix B. The results are summarized in Table 8.5.

Description	Traditional Layout	LID Layout
Earthwork	\$ 23,950	\$ 14,925
Storm Drainage	\$ 102,769	\$ 114,172
Paving & Curbing	\$ 138,657	\$ 53,790
Initial Construction Cost:	\$ 265,376	\$ 182,887
Cost / Sellable Acre:	\$ 42,734	\$ 28,355

Table 8.5. Results of Cost Comparison for Initial Construction Costs

The cost analysis performed for this example shows a cost savings of \$14,379 per sellable acre in initial construction cost for the developer. These results must be combined with a land value comparison to provide a more accurate comparison.

The value of land is highly variable depending on various influencing factors such as proximity to urbanized and or recreational areas. For the purposes of example, a value of \$50,000/acre is assumed as the cost per acre of developed land. This assumed value was used in the cost comparison to provide a basis of comparing traditional vs. LID development. Also, for this example, we have also assumed that some of the costs of constructing the stormwater BMPs will result in a dollar for dollar reduction in the market value of the sellable land. Table 8.6 shows the total land sale value for each layout after subtracting the cost of BMP construction from market value.

Description	Traditional Layout	LID Layout
Total Acres For Sale	6.21	6.45
2009 Market Value/Acre	\$ 50,000	\$ 50,000
BMP Cost/Acre	\$ 0	\$ 12,682
Calculated Market Value/Acre	\$ 50,000	\$ 37,318
Total Land Sale Value:	\$ 310,500	\$ 240,701

Table B.6. Land Sale Value

A final cost comparison is completed by subtracting the initial construction cost from the land sale value to determine the cost difference between the two layouts. For this example, the developer realizes an increase in total profit of \$12,690 by using the LID layout with no additional cost to individual homeowners.

Description	Traditional Layout	LID Layout
Land Sale Value	\$ 310,500	\$ 240,701
Initial Construction Cost	\$ 265,376	\$ 182,887
Total Profit for Project:	\$ 45,124	\$ 57,814

Table B.7. Project Profit

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Discussion of Costs

The cost comparison completed for the design example resulted in similar initial construction costs for each design, with a small final cost advantage for the volume control design. The proposed methods for implementing the proposed stormwater standards can cost less to install, have lower operations and maintenance (O&M) costs, and provide more cost-effective stormwater management and water quality services than conventional stormwater management controls (MacMullan and Reich, 2007). However, the costs and benefits of implementing the proposed stormwater management standards can be very site specific and will vary based on the BMPs used to meet the standards and site characteristics such as topography, soils, and intensity of the proposed development. In a 2007 report summarizing 17 case studies of developments that include LID practices, U.S. EPA concludes that “applying LID techniques can reduce project costs and improve environmental performance”. The report shows total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs. All benefits and costs associated with each option must be considered to find the true cost of implementation on a particular site.

Section IX – Water Quality Impairments and Recommendations

The Clean Water Act is a series of federal legislative acts that form the foundation for protection of U.S. water resources. These include the Water Quality Act of 1965, Federal Water Pollution Control Act of 1972, Clean Water Act of 1977, and Water Quality Act of 1987. The goal of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". Section 305(b) of the Federal Clean Water Act requires each state to prepare a Watershed Assessment Report for submission to the United States Environmental Protection Agency (EPA). The reports include a description of the water quality of all waterbodies in the state (such as this stretch of Oil Creek shown in the above photograph) and an analysis of the extent to which they are meeting their water quality standards. The report must also recommend any additional action necessary to achieve the water quality standards, and for which waters that action is necessary.



Section 303(d) of the Act requires states to list all impaired waters not meeting water quality standards set by the state, even after appropriate and required water pollution control technologies have been applied (EPA, 2008). The law also requires that states establish priority rankings for waters on the list and develop Total Maximum Daily Loads (TMDLs) for these waters. A TMDL is the maximum amount of pollutant that a water body can receive and still safely meet the state's water quality standards for that pollutant. TMDLs are a regulatory tool used by states to meet water quality standards in impaired waterbodies where other water quality restoration strategies have not achieved the necessary corrective results.

IMPAIRED STREAMS

Pursuant to the provisions of the Clean Water Act, DEP has an ongoing program to assess the quality of waters in Pennsylvania and identify streams, and other bodies of water, that are not attaining designated and existing uses as "impaired". Water quality standards are comprised of the uses that waters can support, and goals established to protect those uses. Each waterbody must be assessed for four different uses, as defined in DEP's rules and regulations:

1. Aquatic life.
2. Fish consumption.
3. Potable water supply.
4. Recreation.

The established goals are numerical, or narrative, water quality criteria that express the in-stream levels of substances that must be achieved to support the uses. This assessment effort is used to support water quality reporting required by the Clean Water Act. DEP uses an integrated format for the Clean Water Act Section 305(b) reporting and Section 303(d) listing in a biennial report called the "Pennsylvania Integrated Water Quality Monitoring and Assessment Report". The narrative report contains summaries of various water quality management programs including water quality standards, point source control and nonpoint source control. In addition to the narrative, the water quality status of Pennsylvania's waters is presented using a five-part characterization of use attainment status (DEP, 2008). The listing categories are:

Category 1: Waters attaining all designated uses.

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Category 2: Waters where some, but not all, designated uses are met. Attainment status of the remaining designated uses is unknown because data are insufficient to categorize the water.

Category 3: Waters for which there are insufficient or no data and information to determine if designated uses are met.

Category 4: Waters impaired for one or more designated use but not needing a total maximum daily load (TMDL). These waters are placed in one of the following three subcategories:

Category 4A: TMDL has been completed.

Category 4B: Expected to meet all designated uses within a reasonable timeframe.

Category 4C: Not impaired by a pollutant and not requiring a TMDL.

Category 5: Waters impaired for one or more designated uses by any pollutant. Category 5 includes waters shown to be impaired as the result of biological assessments used to evaluate aquatic life use. Category 5 constitutes the Section 303(d) list submitted to EPA for final approval

VENANGO COUNTY IMPAIRMENTS

If a stream segment is not attaining any one of its designated uses, it is then considered to be "impaired". In Venango County, all of the non-attaining streams were for Aquatic Life use attainment, which is reflective of any component of the biological community (i.e. fish or fish food organisms). The source-cause of impairment varies from stream to stream. Oftentimes, there are multiple source-causes attributed for impairment of a particular stream segment. *Table 9.1* lists the non-attaining streams in Venango County and the source-cause of the pollution. *Figure 9.1* is included for illustrative purposes only and shows a general map of the impaired stream locations.

Classification	Category	Act 167 Watersheds (stream miles) →									
		Allegheny River	East Sandy Creek	French Creek	Oil Creek	Sandy Creek	Slippery Rock Creek	Sugar Creek	Wolf Creek	Entire County	Percent of County
Impaired (miles)	Abandoned Mine Drainage	77.9	9.6	--	--	14.7	3.9	--	--	106.0	6.3
	Agriculture	--	--	--	--	--	--	--	--	0.0	0.0
	Atmospheric Deposition	--	--	--	--	--	--	--	--	0.0	0.0
	Forestry	--	--	--	--	--	--	--	--	0.0	0.0
	Hydromodification	--	--	--	--	--	--	--	--	0.0	0.0
	Industrial or Municipal Point Source	2.7	1.8	--	--	--	1.6	--	--	6.2	0.4
	Urbanization	0.5	--	--	--	--	--	--	--	0.5	0.0
	Source Unknown	15.9	5.0	1.3	11.3	--	--	--	--	33.5	2.0
	Other	--	--	1.9	--	--	--	--	--	1.9	0.1
	Total Impaired	97.0	16.4	3.2	11.3	14.7	5.5	0.0	0	148.0	8.8
	Percent of Total	13.5	9.6	2.6	6.6	8.9	28.0	0.0	0	8.8	8.8

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Stream Name	Source - Cause	Length
		(miles)
West Pithole Creek, Unnamed Tributaries	Urbanization	0.47
Wolf Branch	Source Unknown	1.4
Burford Run	Industrial or Municipal Point Source	1.83
Cogley Run	Abandoned Mine Drainage	1.43
Cogley Run, Unnamed Tributaries of	Abandoned Mine Drainage	1.2
Little East Sandy Creek	Abandoned Mine Drainage	2.86
Prairie Run	Abandoned Mine Drainage	1.67
Prairie Run, Unnamed Tributaries of	Abandoned Mine Drainage	1.35
Tarkiln Run	Abandoned Mine Drainage	0.6
Tarkiln Run	Source Unknown	4.22
Tarkiln Run, Unnamed Tributaries of	Abandoned Mine Drainage	0.48
Tarkiln Run, Unnamed Tributaries of	Source Unknown	0.74
French Creek, Unnamed Tributaries of	Other	1.86
French Creek, Unnamed Tributaries of	Source Unknown	1.34
Oil Creek	Source Unknown	11.06
Oil Creek, Unnamed Tributaries of	Source Unknown	0.23
South Sandy Creek, Unnamed Tributaries	Abandoned Mine Drainage	2.39
Sulphur Run	Abandoned Mine Drainage	1.97
Sulphur Run, Unnamed Tributaries of	Abandoned Mine Drainage	2.04
Williams Run	Abandoned Mine Drainage	6.38
Williams Run, Unnamed Tributaries of	Abandoned Mine Drainage	1.87
Blacks Creek	Abandoned Mine Drainage	0.66
Blacks Creek, Unnamed Tributaries of	Abandoned Mine Drainage	0.89
North Branch Slippery Rock Creek	Industrial or Municipal Point Source	1.64
North Branch Slippery Rock Creek, Unnamed Tributaries of	Abandoned Mine Drainage	2.35
TOTAL IMPAIRED LENGTH =		148.03

Table 9.1. Non-Attaining Streams in Venango County

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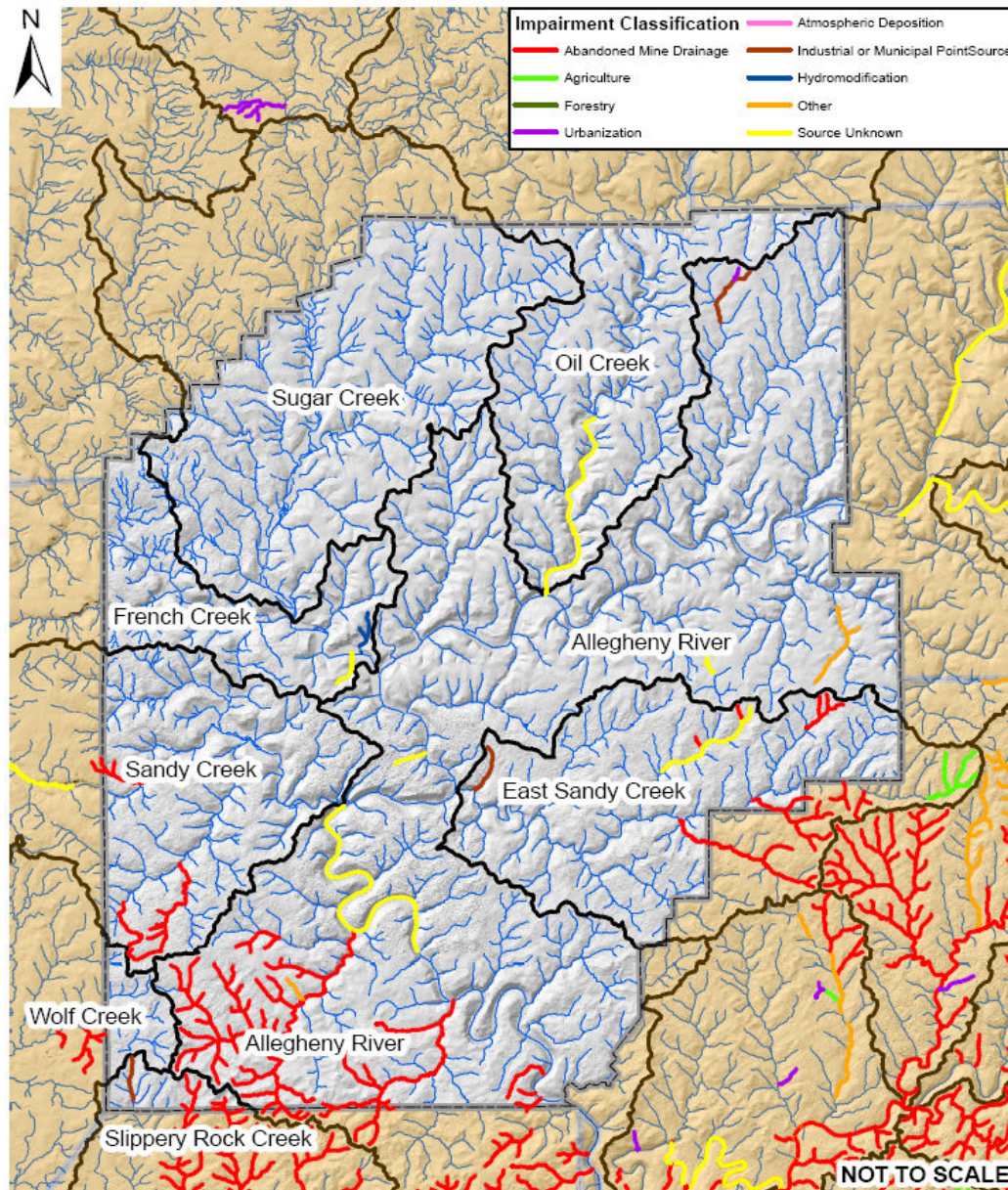


Figure 9.1. Impaired Streams in Venango County

TMDL DISCUSSION

Once a waterbody is listed on the EPA approved 303(d) list, it is required to be scheduled for development of a TMDL. TMDLs are expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a water quality standard. They can be developed to address individual pollutants or groups of pollutants, if it is appropriate for the source of impairment.

A TMDL must identify the link between the use impairment, the cause of the impairment, and the load reductions needed to achieve the applicable water quality standards. However, a precise implementation plan is not part of the approved TMDL. A TMDL is developed by determining how much of the pollutant causing the impairment can enter the waterbody without exceeding the water quality standard for that particular pollutant. The calculated pollutant load is then distributed among all the pollutant sources as follows:

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$$TMDL = WLA + LA + MOS$$

Where: TMDL = Total Maximum Daily Load

WLA = Waste Load Allocation; from point sources such as industrial discharges and wastewater treatment plants

LA = Load Allocation; from nonpoint sources such as stormwater, agricultural runoff and natural background levels

MOS = Margin of Safety

TMDLs are developed by the State and submitted to EPA for review and approval. Once a TMDL has been approved, it becomes a tool to implement pollution controls. It does not provide for any new implementation authority. The point source component of the TMDL must be implemented through existing federal programs with enforcement capabilities (e.g. National Pollution Discharge Elimination System, NPDES). Implementation of the Load Allocations for nonpoint sources can happen through a voluntary approach, or by means of existing state or local regulations. *Table 9.2* lists all the TMDLs in Venango County.

Waterbody	TMDL Category	Cause	Status
Little Scrubgrass	AMD	Metals, pH	EPA Approved 5-15-2007
Lockard Run Watershed	AMD	Metals, pH	EPA Approved 4-9-2001
Scrubgrass Creek Watershed	AMD	Metals	EPA Approved 5-19-2008

Table 9.2. TMDLs in Venango County

CRITICAL SOURCES OF IMPAIRMENT

The primary causes of water quality impairment are sediment/siltation, nutrients, metals, and pathogens. Nonpoint source (NPS) pollution is a general term for water pollution generated by diffuse land use activities rather than from an identifiable or discrete facility. In Pennsylvania the leading nonpoint sources of impairment are:

- Abandoned Mine Drainage (AMD)
- Agriculture
- Urban Runoff/Storm Sewers
- Road Runoff
- Forestry
- Small Residential Runoff

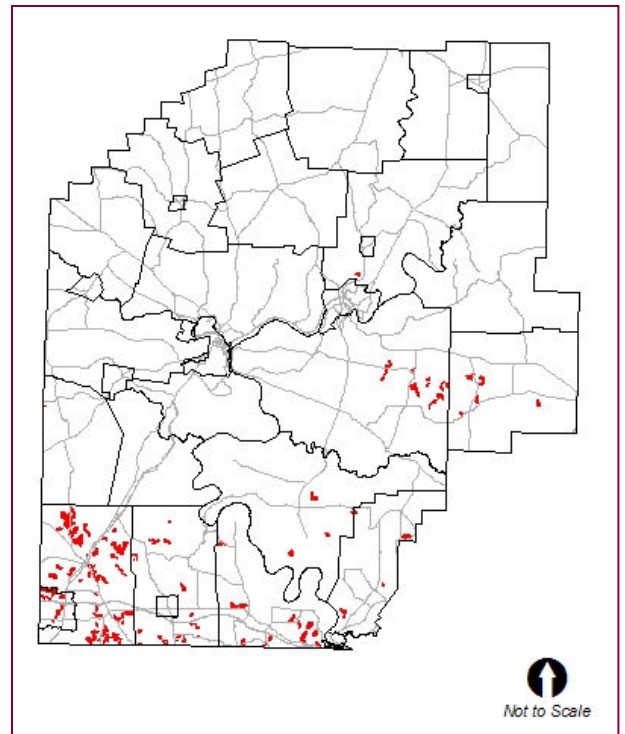
Some of these sources are regulated by stormwater ordinances and have been covered in previous section. However, several of these categories are more appropriately addressed by other regulations. Although these activities cannot be regulated by the provisions of the stormwater management ordinance of this Plan, they play a major role in the water quality of surface waters. The following is a summary of some nonpoint sources and related causes for impairment that affect Venango County waters:

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ABANDONED MINE DRAINAGE (AMD)

Contaminated water seeping from abandoned coal mine areas (commonly known as abandoned mine drainage, or AMD) is one of the most prevalent and severe water pollution problem in Pennsylvania. AMD, impairing nearly 106 miles of surface waters within the county, is the primary cause of impairment in Venango County. Impacting approximately 6% of the impaired waters within the county, AMD is, by far, the principal impairment concern. There are many different potential contaminants found in and around abandoned mines

Years of coal mining that was conducted before the regulation of the industry and a sharp decline in production have left behind a multitude of abandoned mine sites that host a variety of environmental and safety issues. Abandoned mine sites have left dangerous highwalls, open pits, coal refuse spoil piles, old mine openings, and miles of streams polluted by abandoned mine drainage. Past coal mining practices have led to erosion, landslides, polluted water supplies, destruction of fish and wildlife habitat, and an overall reduction in natural beauty. Abandoned mines leak acidic, metal-contaminated waters into nearby waterways and the ground water.



Many strip mines were not backfilled or re-vegetated, allowing water to infiltrate through acidic spoil, settle into impoundments and contaminate groundwater supplies. Strip mine activities often removed the outcrop barrier allowing groundwater to flow unimpeded to the surface over the old strip pit. The refuse produced from mining activities (consisting of high sulfur material) was usually just stockpiled, another source of pollution. The problems caused by Abandoned Mine Sites can be classified in several categories:

SAFETY PROBLEMS – Abandoned mine land (AML) sites have contributed to deaths in several states. Highwalls, open shafts, dilapidated mine structures, and water-filled pits present serious health and safety threats.

ECONOMIC PROBLEMS – These lands are often located in the most economically depressed areas of our nation. All that remains in many once populated mining communities are scarred lands and a few residents who are willing to commute to larger cities for employment. The AML sites make it difficult to compete for industry and tourism.

AESTHETIC PROBLEMS – The sparse vegetation (if any), stagnant water and illegal trash dumps characterization of AML sites have a negative effect on everyone. The appearance of the site tends to depress land value and detract from the tax base. The environmental scars contribute to an apathetic attitude toward the condition of these areas.

WATER PROBLEMS – Acid run-off and sedimentation from abandoned mine sites contaminate thousands of miles of streams nationwide. This contaminated water eventually serves as potable water supply; therefore, an increase in water treatment costs is needed. Acid mine drainage also leads to increased road maintenance costs, due to the corrosive effects of this drainage on culverts. Streams and drainage systems are often clogged by sedimentation from abandoned mine sites, which, in turn, may cause flooding as a secondary result.

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The Surface Mining Conservation and Reclamation Act of 1971, and the Federal Surface Mining Control and Reclamation Act of 1977 have generated regulations intended to eliminate and control adverse conditions resulting from mining operations. Still today, the County lives with the legacy of coal mining.

In Venango County there have been many reclamation projects completed and more are in progress. According to DEP, 2010 Growing Greener funding in an amount of \$30,000 has been awarded to the South Sandy Creek Watershed Association to sample and identify the contents of a coal refuse pile to determine if it can be burned for fuel by a co-gen power plant. Removal of the pile will abate one of the largest sources of acid mine drainage in Williams Run.

URBANIZATION

This is a broad category that includes the following three critical sources of impairment listed earlier in this section: 1) Urban Runoff/Storm Sewers, 2) Road Runoff, and 3) Small Residential Runoff. These sources have been grouped together because they are all types of urbanization, or human development activities. When development activities replace forests, fields, and meadows with impervious surfaces the landscape's capacity for initial abstraction (or initial depth of water absorbed by ground cover) is greatly reduced and surface runoff increases. This topic has been the focus of this Plan. The quantity of runoff from urbanized areas, and the water quality characteristics of the runoff, is the two base causes of surface water impairments. These two primary pollutants translate into surface water impairments in several different forms.

SEDIMENT/SILTATION

As stormwater flows over land it collects silt and sediment and carries them to surface waters. Urbanization decreases the opportunity for natural filtration of runoff through vegetation and often concentrates flow in discharges that cause increased overland erosion. The increased rate of stormwater flow and increased sediment load delivered to the stream combine to raise the in-stream energy. This in turn changes the physical structure of the receiving streams by causing increased bank erosion as well as scour of the streambed and sedimentation when the water finally slows down. Increased sediment loading in a stream contributes to increased total suspended solids and turbidity, which can in turn lead to increased stream temperatures as darker particles absorb heat (EPA, 1997). As water temperature rises and dissolved oxygen levels decrease. These changes caused by sediment and siltation are all substantial contributors to aquatic life impairments.

HABITAT ALTERATIONS

Natural channels are composed of alternating sequences of pools, riffles, and runs. The diverse characteristics of each of these features provide unique habitats that allow various aquatic species to live, feed, and reproduce (EPA, 2007). The elevated stream power that occurs when additional runoff and sediment loading are experienced causes physical alterations to the stream channel. The increased energy carries large debris downstream, erodes streambeds and banks, creates scour holes at existing structures, and deposits new sediment in the channel as flows subside. These changes can drastically alter the structure of pools, riffles, and runs and eventually diminish the quality of the habitat to a point where the stream can no longer support aquatic life.

NUTRIENTS AND METALS

As runoff flows over impervious surfaces it picks up various pollutants and transports them to waterbodies. This includes oil and grease from automobiles; fertilizers, herbicides and pesticides from lawns; fecal matter from pet waste and malfunctioning septic tanks; chlorides from winter road maintenance; and heavy metals from tires, shingles, paints, and metal surfaces. These

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pollutants degrade water quality and limit the beneficial uses of the surface waters. Beneficial uses that may be impacted include drinking water supply, swimming, fishing, other recreation, and aquatic life support.

HYDROMODIFICATION

Hydromodification is an alteration to the natural flow of water through a landscape. It is one of the leading sources of impairment in streams, lakes, estuaries, aquifers, and other waterbodies in the United States. Four major types of hydromodification activities change the physical characteristics of a waterbody, as well as its natural function:

1. Channelization and channel modification,
2. Dams,
3. Culverts and Bridges, and
4. Streambank and shoreline erosion

Hydromodification activities are almost always undertaken out of a desire to improve our ability to use land and water resources, or to protect human health and/or safety. However, hydromodification activities sometimes have unintended consequences (as exhibited in the adjacent photograph, located north of Franklin), and almost always result in some degree of water quality and habitat impacts. These changes can cause problems such as changes in flow, increased sedimentation, higher water temperature, lower dissolved oxygen, degradation of aquatic habitat structure, loss of fish and other aquatic populations, and decreased water quality.



The most significant physical change caused by hydromodification is sedimentation and siltation. If a modification occurs that causes a change in sediment load, channel slope, or streamflow the stream will attempt to regain its dynamic equilibrium by either increasing sediment discharge through bed scour and bank erosion (degradation) or by reducing sediment discharge by depositing sediment on the bottom (aggradation) (EPA, 2007). Sediment and siltation can lead to increased turbidity, increased stream temperature, and decreased dissolved oxygen. Excessive quantities of sediment can bury benthic organisms and the habitat of fish and waterfowl. Suspended solids in the water reduce the amount of sunlight available to aquatic plants cover fish spawning areas and food supplies, fill rearing pools, reduce beneficial habitat structure in stream channels, and clog and harm the gills of fish (EPA, 2007). These changes are all substantial contributors to aquatic life impairments.

In-stream structures such as dams, culverts, and bridges can also have significant impacts on a stream. These structures can alter streamflow, reduce or increase sediment discharge, block aquatic organism passage, alter and change various water quality aspects. The impacts vary depending on the type and size of the structure. For example, small, low-head dams with little impounded areas will exhibit different impacts than large storage dams. Sedimentation and fish passage issues at the smaller, low-head dam contrast with sedimentation, temperature, fish passage, flow regulation, and water quality issues that may be associated with the larger storage dam (EPA, 2007).

Section IX – Water Quality Impairments and Recommendations

RECOMMENDATIONS

Addressing water quality impairments is achieved most effectively through watershed wide planning and implementation. The water quality based approach is a common method of addressing impairments. The "Integrated Waters List" identifies impaired streams and identifies source-causes of impairment. The next step towards improving the water quality in these streams is to identify the critical areas within the impacted watershed. Critical areas are the geographic regions within a watershed that directly contribute pollutants to the stream. The primary purpose for identifying critical areas is to develop a strategy that effectively addresses the sources of water quality impairment.

An inventory of each watershed that identifies the critical areas allows time, effort, and funds to be targeted towards those sites that most negatively impact water quality. This stage should be completed by a watershed planner with the technical knowledge necessary to accurately identify critical areas and the ability to provide a technical assessment of the severity of each source. The planner will need to prioritize the inventoried sites within the critical area based on the degree to which the sites contribute to the impairment and the overall objectives of the community.

It is important to involve the stakeholders within the watershed at this point in the form of a steering committee. A group such as a local watershed group or the County Conservation District would be able to assist in identifying the stakeholders and coordinating everyone's efforts. The planner and steering committee will work together to develop a comprehensive watershed plan and an implementation strategy to address the sites within the critical areas. The goal is to address the most severe sources of pollutants in an efficient manner. The next step in developing a comprehensive watershed plan is to set definable water quality goals based on the detailed inventory.

Developing an implementation strategy and determining specific BMPs to treat specific sites is the last step. Existing water quality programs should be considered as the implementation strategy is developed. These programs can be coordinated with the implementation strategy in order to achieve a common goal. Thought must also be given to potential funding sources and how they can be used to implement portions of the overall water quality improvement plans. As projects are implemented, the plan should be reviewed and revised as necessary to ensure that the water quality goals are eventually obtained.

Section X – Additional Recommendations and Considerations

The stormwater management standards developed in this Plan are the basis for sound stormwater management throughout the county. However, there are many activities that fall outside the scope of stormwater management regulations that have a significant impact on stormwater runoff and the goals of sound stormwater management planning. Generally, standards for many of these activities are contained within Zoning Regulations and Subdivision and Land Development Ordinances. Some of these activities and their impact on stormwater management are discussed below.



These measures are included here because they are beyond the regulatory scope of this Plan but may provide valuable tools in obtaining the goals discussed in *Section II*. It is suggested that all municipalities consider these additional recommendations, and determine whether adoption of some of these policies could be beneficial to their respective communities. Municipalities with substantial stormwater problem areas could especially benefit from regulation of some, or all, of these activities. A holistic approach that considers all land use policies, and how they impact stormwater runoff, is necessary to maximize the effectiveness of a stormwater management program.

MUNICIPAL ZONING

Municipal zoning is perhaps the single most influential factor on a stormwater management program. This is because the rainfall-runoff response of a given geographical area is directly linked to land use. In this manner, zoning regulations can help achieve the goals of a stormwater program or they can be a hinderance to successful implentation of the program. Only 34% of rural municpalites have enacted zoning ordinances and the majority of these are located in the southeast portion of the Commonwealth (Center for Rural Pennsylvania, 2001). Instituting new zoning regulations, or even changes to existing regulations, can be very difficult. Potential obstacles may include political backlash from a perceived overreach in municipal regulation, increased enforcement costs, and a lack of professional staffing (often related to a lack of financial resources) in the development of regulations.

Despite the difficulties associated with implementing zoning regulation changes, this is a vital element of a successful stormwater management program. This being said, the impacts of zoning regulation reach far beyond stormwater management. Zoning changes should be developed with careful consideration of all of the potential effects of the ordinance changes.

Recommendations for Improved Municipal Zoning

The following zoning tools are recommended by the Center for Watershed Protection that, if possible to implement, may aid in achieving the stated goals of this Plan (Center for Watershed Protection, 1999):

- **Watershed Based Zoning** – Master planning efforts and zoning incorporate recommendations for individual watershed, with watershed specific regulations. Long-term monitoring and evaluation of the effectiveness of the regulations should be part of the program.

Section X – Additional Recommendations

- **Overlay Zoning** – With this option, specific criteria can be applied to isolated areas without the limitations of underlying base zoning. Overlay zoning superimposes additional regulatory standards, specifies permitted uses, or applies specific development criteria onto existing zoning provisions. Overlay zones may take up only part of an underlying zone or may encompass several underlying zones. An example of watershed-related overlay zoning may be “Impervious Overlay Zoning” in areas with documented stormwater problems, which sets a maximum impervious area cap.
- **Performance Zoning** – This technique requires a proposed development to ensure a desired level of performance within a given area. This method has been used to control traffic or noise limits, light requirements, and architectural styles. Watershed-related performance zoning might provide precise limits on stormwater quality and quantity. This may be one option to address impaired waters.
- **Large Lot Zoning** – This type of zoning district requires development to occur at very low densities to disperse impervious cover. This concept may be in conflict with some development goals, and encourages sprawl, thereby impacting stormwater related to future development.
- **Urban Growth Boundaries** – Growth boundaries set dividing lines for areas designated for urban and suburban development and areas appropriate for traditionally rural land uses, such as agriculture and forest preservation. Growth boundaries are typically set for up a specific time period (e.g. 10 to 20 years) and re-evaluated at appropriate intervals.
- **Infill Community Redevelopment** – This strategy encourages use of vacant or under-used land within existing growth centers for urban redevelopment. This practice is one method used to reduce the negative impacts of urban sprawl and minimize additional impervious area by maximizing utilization of existing infrastructure.
- **Transfer of Development Rights** – This allows transfer of development rights from sensitive subwatersheds (where the potential for adverse impacts is relatively high) to other watersheds designated for growth (where the potential for adverse impacts are relatively low).

RIVER CORRIDOR PROTECTION

River corridor protection is a very broad term that encompasses several closely related river (the term river is used loosely here to include all rivers, streams, creeks, etc.) management approaches. River corridors provide an important spatial context for maintaining and restoring the river processes and dynamic equilibrium associated with high quality aquatic habitats (Kline, 2008). The river corridor includes the existing channel, the floodplain, and the adjacent riparian zone. The basic concept behind river corridor protection is recognizing the natural functions of rivers and streams and managing them to resolve conflicts between the natural systems and human land use.

Rivers and streams adjust over time through dynamic fluvial processes in response to the varying inputs of water, sediment, and debris. Natural adjustments to these inputs are occurring continually in rivers and streams. These adjustments are generally minor and occur over long time periods. The result of these processes is evidenced in streambank erosion, channel incision, meandering stream channels, and the inevitable conflict between the stream and nearby human infrastructure. The more significant changes, such as channel relocation, usually occur during large flood events. River corridor protection includes the following management strategies to complement a stormwater management program:

Section X – Additional Recommendations

FLOODPLAIN MANAGEMENT

There is a direct relationship between stormwater management and floodplain management. Stormwater management policy focuses on future development and reducing the likelihood of increased flooding while floodplain management focuses on preventive and corrective measures to reduce flood damage. Implementation of the Model Stormwater Management Ordinance will reduce the probability of new flooding problems, but will have only minor impacts on existing problems. Examples of these problems are documented in *Section V – Significant Problem Areas and Obstructions*. Many of these problems are due to historic development that has occurred in the floodplain and inadequately sized infrastructure. Floodplains are necessary to convey and attenuate the natural peak flows that occur during major hydrologic events.

As discussed in *Section III*, Venango County incurs a substantial economic loss in major hydrologic events (as much as \$61 million in a 10-year storm event). Floodplain management policy serves to minimize the impact of such events by reducing the conflicts between human infrastructure and floodplains. While improved stormwater management will greatly reduce the occurrence of nuisance flooding, floodplains are necessary to attenuate flood waters from events that exceed the intended scope of stormwater policy. The most effective floodplain management policy provides preventive provisions that restrict future development within floodplains and corrective measures that reduce flood damage in existing problem areas.

Recommendations for Floodplain Management

- **Adopt and enforce the Pennsylvania Department of Community and Economic Development (DCED) Model Floodplain Ordinance.** When the FIRMs in Venango County were updated, it was strongly recommended by DCED that each municipality adopt the DCED model ordinance. This will ensure that the local ordinance addresses the minimum state and federal requirements of the NFIP and provide a consistent basis of floodplain management between all of the municipalities in the county.
- **Participate in the Community Rating System.** The CRS gives communities credit for reducing the risk of flood hazards. By implementing many of the same principles that are discussed in this Plan, municipalities can reduce flood insurance rates for residents inside of floodplains by up to 45%.
- **Provide open space preservation in floodplain areas.** Open space preservation may also provide credits to future developments by reducing impervious area and thereby reducing stormwater requirements.
- **Acquire and relocate flood-prone buildings so they are no longer within the floodplain.** Repetitive loss properties (properties for which two or more claims of at least \$1000 have been paid by the NFIP within any 10-year period since 1978) constitute a large portion of the NFIP flood insurance claims. Nationally, less than 2% of all properties have accounted for 33% of flood insurance claims since 1978 (FEMA, 2002). Removing these and any other structure that incurs flood risk on an annual basis reduces the overall risk of the NFIP and reduces the community's exposure to flood damage. It is usually more economical to remove properties, particularly in rural areas like Venango County, than to install structural alternatives such as levies, diversion projects, or dams.
- **Implement a drainage system maintenance program.** As noted in *Section V*, there are numerous locations where clogged or poorly maintained facilities result in flooding of areas not normally prone to flooding. Most engineering design calculations for stormwater detention and conveyance facilities assume full function of a bridge or culvert. Implement a systematic inspection and maintenance program where periodic

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inspections are conducted on all channels, conveyance, and storage facilities and remove debris and perform maintenance as necessary.

RIVER CORRIDOR PLANNING

River corridor planning is a process for selecting and implementing river corridor management alternatives in which all aspects of the river are considered. The process is accomplished through river specific assessments and planning that is able to characterize the river and identify important features as well as the areas that are susceptible to potential threats to those features. This is a form of land use planning that focuses on the impacts of land use on the river system.

One particularly useful aspect of river corridor planning is to use the assessment information to designate corridors along the rivers where natural river changes are most likely to occur resulting in accelerated erosion or bank failures. These areas are sometimes referred to as “fluvial erosion hazard zones” and are responsible for a large portion of the damage to human infrastructure during flood events (Dolan, 2008). Once these areas are identified and mapped, land use planning mechanisms are used to protect identified sensitive areas and limit future development within this zone. Keeping infrastructure, such as roads and utilities, out of the high risk areas greatly reduces the cost of protecting and maintaining this infrastructure.

Recommendations for River Corridor Planning

- **Identify areas that could benefit from river corridor planning and initiate the planning process.** Identifying areas that could benefit from improved river corridor management can protect river resources and greatly reduce the economic impact caused by major hydrologic events. River corridor planning can be especially beneficial in areas with special value, areas that are likely to receive considerable future development near the river, or areas that currently experience persistent flood damage.
- **Identify and protect fluvial erosion hazard zones.** Flood damage may also occur as a stream channel changes course and meanders. The channel changes may result from either naturally occurring geologic processes or human-induced changes to watershed hydrology or hydraulics. A geomorphic assessment can identify the areas that are most likely to experience channel changes through erosion. These areas can then form the basis for an overlay zoning district or area with specified stream buffers for additional protection. Another option that has been implemented in the state of Vermont, is to integrate Fluvial Erosion Zones into the floodplain mapping process, so that all of the tools of floodplain management are available for the specified areas (Vermont Agency of Natural Resources, 2009).

RIPARIAN ZONE PROTECTION

The riparian zone is the transitional zone between the aquatic zone and adjacent uplands. It generally includes the streambanks, flood plain, and any adjacent wetlands. The riparian zone is often overlapping with the river corridor, but has a slightly different connotation. The term riparian zone does not refer to an explicit width, rather a width that varies along the length of a given stream depending on the geography of the area. Natural riparian zones are typically covered with trees, shrubs, and other types of local vegetation, all of which provide a natural buffer between waterways and human land use as well as providing vital and unique natural habitat.

Riparian zones provide two principal benefits in regards to stormwater management. They offer flood protection by providing temporary storage area, slowing the velocity of flood waters, and provide a small amount of volume reduction through infiltration and permanent retention of water by disconnected low lying areas. The second primary benefit of riparian zones is the water

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quality functions they offer. The vegetation in the riparian zone provides shade that reduces water temperature, traps and removes pollutants from stormwater, and provides protection from streambank erosion.

Recommendations for Riparian Zone Protection

- **Adopt and enforce the riparian buffer provisions of the Model Stormwater Management Ordinance.** The Model Ordinance includes provisions to require establishment of riparian buffers on all new development that occurs near watercourses. This will provide riparian zone protection by creating buffers between stream segments and all future development.
- **Establish a riparian zoning overlay district.** Identify critical riparian areas in which existing land uses may not be achieving water quality, floodplain management, and stormwater management objectives. Use this inventory of critical riparian zones to create a riparian zoning overlay district that establishes regulations on activities inside the zoning district.
- **Adopt stream specific guidelines where appropriate.** Where numerous problems areas have been identified and a riparian buffer is identified as a potential solution, a municipality may wish to adopt a stream specific set of guidelines that consider the specific fluvial geomorphological processes of that stream. A stream corridor study may be prepared that designates varying widths along a reach of stream. An ordinance that uses a stream corridor study as its basis will establish buffer widths using the best available scientific data. Some buffer ordinances have zones that vary between 75' and 1000' depending on the scientific and economic justification (Wenger and Fowler, 2000).
- **Encourage voluntary establishment of riparian buffers.** A regulatory approach will limit future development within the riparian zone, but will have little affect on existing land uses in critical riparian areas. There are numerous existing incentive programs that offer technical and/or financial assistance to encourage land owners to alter existing land uses and establish riparian buffers. These include agricultural land retirement programs such as USDA's Conservation Reserve Enhancement Program (CREP) program, cost-share programs such as USDA's Environmental Quality Incentives Program (EQIP), as well as grant and loan programs.

WETLAND PROTECTION

Wetlands play an essential role in stormwater management and water quality protection, as well as providing other valuable ecological and cultural functions. Some of the functions wetlands provide relevant to stormwater include: storm flow modification, erosion reduction, flood control, water quality protection, sediment and nutrient retention, and groundwater replenishment. Wetlands associated with lakes and streams provide temporary storage of floodwater by spreading the water over large flat areas, essentially acting as natural detention basins. This decreases peak flows, reduces flow velocity, and increases the time period for the water to reach the watershed outlet. Novitzki (1979, 1989) found that basins with 30 percent or more areal coverage by lakes and wetlands have flood peaks that are 60 to 80 percent lower than the peaks in basins with no lake or wetland area.

Wetlands can also maintain good quality water and improve degraded water. Wetland vegetation also decreases water velocities causing suspended solids to drop out of suspension, thus decreasing the erosive power of the water. Wetlands also trap, precipitate, transform, recycle, and export sediment, as well as nutrients, trace metals, and organic material. Water

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leaving a wetland can differ noticeably from that entering (Mitsch and Gosselink, 1993; Elder, 1987).

Recommendations for Wetland Protection

- **Identify and protect special value wetlands.** Due to the diversity of the benefits provided by wetlands, they are protected through various levels of federal and state regulations. These regulations protect wetlands from development; however, they permit minor wetland encroachments for certain activities. Some wetlands provide specific ecological or stormwater related benefits to an area. These wetlands should be identified and further protected through municipal regulations.

LOW-IMPACT DEVELOPMENT SITE DESIGN

The basic principles and concepts of LID were covered in *Section I* along with some of the benefits of implementing LID stormwater management practices. These concepts have been further developed throughout this Plan. This information has primarily discussed LID concepts as they relate to stormwater management. However, there are many non-stormwater LID practices that can have a very positive impact on a stormwater management program.

Development alters the natural landscape with human infrastructure like buildings, roads, sidewalks, parking lots, and other impervious surfaces. As previously discussed, all of these “improvements” alter the natural hydrology of a site and generate increased runoff. LID site design concepts include reducing impervious surface area, minimizing the amount of natural area disturbed during development, decentralizing stormwater management facilities, and generally attempting to minimize the effects of development on natural resources. Stormwater management can be improved by encouraging use of additional LID practices.

LIMIT IMPERVIOUS COVER

Increased impervious area within a watershed is a direct contributor to increased storm flows and decreased water quality. Research in recent years has consistently shown a strong relationship between the percentage of impervious cover in a watershed and the health of the receiving stream (USEPA, 2009). Various studies have indicated that as overall watershed imperviousness approaches 10% biological indicators of stream quality begin to show degradation. Limiting impervious cover is one method of reducing the impact of development on the hydrologic cycle.

Recommendations to Limit Impervious Cover

Some alternative development approaches within the LID approach include cluster development, reduction in street widths, reduction in parking space requirements (number and/or sizes), and creating a maximum impervious percentage on individual lots. Some specific elements within the LID framework include the following:

- **Road Widths** – These are usually specified based on the anticipated road use category (e.g., major, minor, collector). Most ordinances assume a standard 12-foot wide travel lane and then add width for shoulders, parking lanes, bicycle lanes, and other considerations. Reducing the travel lane width to 11 feet for minor roads (e.g., roads within a subdivision development) could reduce the impervious cover of those roadways by up to 8 percent.
- **On-Street Parking** – Parking lanes are often specified to be 8 or 10 feet wide. Standardizing the maximum width of these lanes to 8 feet would reduce runoff. Also, limiting parking to one side of a street, particularly in subdivisions, could result in a

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significant reduction in total runoff. Another option would be to require that the parking lanes be constructed of pervious pavement, grid blocks or another pervious surface.

- **Sidewalks** – In instances where ordinances require sidewalks, consideration should be given to only requiring them on one side of the street in order to reduce impervious cover. Also, sidewalks should be separated from the roadway surface by a “green strip” (e.g., grass or shrubs) to allow runoff from the impervious surface an opportunity to infiltrate before entering the roadway drainage system. In fact, the sidewalks could, in some instances, be laid out so that they do not parallel the roadway, providing even greater opportunity for infiltration.
- **Curb and Gutter Systems With Storm Sewers** – In heavy residential areas, many ordinances require the developer to install curb and gutters along roadways and to use inlets and storm sewers to remove and transport the runoff from the roads. Ordinances should be modified to allow roadside swales that would provide additional infiltration opportunity and some water quality benefit through filtration. This option would have the added benefits of significantly reducing development costs and minimizing future maintenance requirements.
- **Parking Requirements and Parking Stall Dimensions** – Consideration should be given to reducing the number of parking spaces that must be provided on-street or in parking lots for residential, commercial, educational, and industrial developments. Furthermore, stall sizes in parking lots should be set to 8-feet wide by 18-feet long. In addition, consideration could be given to requiring that larger parking lots establish special areas for compact cars with stall sizes reduced to 7-feet wide by 15-feet long. Finally, the ordinances should include requirements for a minimum amount of “green space” in parking lots which should allow runoff from the impervious surfaces to flow over them so that infiltration and water quality filtration would be enhanced.
- **Lot Sizes and Total Impervious Cover** – Most ordinances establish minimum lot sizes for various types of development and the number of “units” permitted on each lot. However, the ordinances do not always limit the amount of impervious cover that can be built on a specific lot, particularly in residential developments. Limits should be established and those limits should be used in determining the “post-development” runoff condition when designing the proposed storm water management systems. In addition, requirements should be established for the minimum amount of “green space” that should be provided in commercial, educational, and industrial developments and these “green spaces” should be designed so that runoff from the impervious surfaces can flow over them to the maximum extent practical.
- **Lot Setbacks** – There are at least two schools of thought regarding lot setbacks as they relate to stormwater management: 1) Minimizing lot setbacks will reduce driveway lengths and, thereby, reduce total impervious cover and 2) Maximizing lot setbacks will allow runoff from impervious surfaces (e.g., roof tops) greater opportunity to infiltrate prior to reaching roadway drainage systems. Either method could be beneficial as long as the method works in coordination with the other Ordinance requirements.

LIMIT DISTURBANCE OR COMPACTION OF TOPSOIL

Topsoil is an absorbant top layer that provides significant stormwater management functions through initial abstraction. During rainfall events, no runoff occurs until the topsoil becomes saturated and the initial holding capacity of the soil is exceeded. The void spaces in undisturbed topsoil can provide significant water storage. The ability for initial abstraction can alter drastically from one soil type to another or because of varied site conditions. However, soil compaction plays a significant role in the ability of a given soil type to hold water. As topsoil is disturbed, or

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compacted, the holding capacity of the soil is drastically reduced, thus limiting its effectiveness in reducing runoff. Previous studies (Gregory, 2006) have shown that compacted pervious area effectively approaches the infiltration behavior of an impervious surface.

Recommendations for Topsoil Management

- **Adopt ordinance language that discourages the common practice of removing all topsoil from development sites during construction.** The area of disturbance during a project should be limited to the minimum area necessary to complete the project. This provides the dual benefit of limiting erosion during construction and improving post construction stormwater management.
- **Adopt ordinance provisions that limit soil compaction where possible.** Areas that are not disturbed should be protected from compaction by construction activities to the maximum extent practicable. These areas should be designated on site plans and demarcated and protected by in-field measures. This is especially important for areas intended for infiltration based stormwater management facilities.

IMPEDIMENTS TO LID IMPLEMENTATION

The LID concept has been around for a long time, but has been slow to catch on in mainstream implementation. In an effort to assess the impediments to LID in the Chesapeake Bay portion of Virginia, Lassiter (2007) identified and ranked several impediments to LID implementation. The two most important impediments identified were 1) lack of education about the LID concept and 2) existing development rules that conflict with LID principles.

Other recent studies have found that existing municipal regulations are often a significant impediment to LID implementation (*Chesapeake Bay Program, 2002*). Many existing municipal regulations were developed to provide adequate infrastructure to meet the needs of growing communities. Often times these standards encourage use of unnecessary impervious surfaces such as extra wide streets in small residential areas, parking spaces for “worst-case scenarios” that get used only a few times a year, and dead-end sidewalks. Municipalities are encouraged to review their ordinances for regulations that conflict with low-impact development and revise them to encourage the use of LID site design. There are many direct economic, environmental, aesthetic, and social benefits for a municipality adopting LID-friendly Ordinances.

Recommendations to Remove LID Impediments

- **Provide education activities and training workshops to various stakeholder groups.** As decision makers, and the group responsible for setting policy, municipal and county officials should be encouraged to obtain additional education on LID practices. Other stakeholders such as developers, builders, and homeowners should also have educational resources available to increase awareness and encourage implementation of LID practices. Education is the key to successful implementation of LID practices.
- **Promote guidance documents such as this Plan and included references.** There are a variety of publications and internet sites that discuss LID and offer design solutions: Low Impact Development Center (2009), DEP (2006), and Prince George's County (2000). These resources should be made available through municipal offices, websites, or trainings.
- **Alter existing Subdivision and Land Development Ordinances and Zoning Ordinances to allow for successful LID implementation.** Adoption of the Model Stormwater Management Ordinance in this Plan is an important tool in accomplishing the goals of

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LID. However, it is recommended that municipalities modify and enhance ordinances in order to provide enough flexibility to allow these innovative design methods to be employed by developers in order to advance the goals of this Plan. Potential alterations that may help create flexibility include: 1) creation of overlay zoning, 2) providing amendments to Ordinances to support LID efforts (i.e. reducing impervious cover and limiting topsoil compaction), or 3) creating an expedited waiver process for LID-specific requests.

- **Provide incentives for LID implementation.** Lassiter (2007) identifies tax credits, allowing for higher density developments, mitigation credits, and reduced land development fees for sites with LID developments as potential incentives to encourage developers to use LID.
- **Keep an inventory of LID efforts to help provide County-specific recommendations and successful BMP installation.** While considerable documentation exists on specific BMPs (e.g. National Research Council, 2008; DEP, 2006), very little scientific data exists within this region, and particularly this County. A valuable part of LID, one that is too often neglected, is the component of encouraging debate and expanding the LID knowledge base. Having an agency with a central role in land development permitting such as the Conservation District would be invaluable to developers and design professional in determining what works in Venango County – and what may not.

SUMMARY

Implementation of the standards developed in this Plan are a necessary step towards developing a holistic stormwater management plan, but much more can be done to improve how we manage water resources. There are many opportunities for local governments to improve the way this resource is managed, and protected, and the benefits are vast for those who undertake the challenge. There is a substantial number of technical resources available to guide development of regulations for proactive thinking municipalities.

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Section XI – Plan Adoption, Implementation and Update Procedures

PLAN REVIEW AND ADOPTION

The opportunity for local review of the draft Stormwater Management Plan is a prerequisite to county adoption of the Plan. Local review of the Plan is composed of several parts, namely the Plan Advisory Committee review (with focused assistance from others including Legal Advisors and Municipal Engineer's review, Municipal review), and County review. Local review of the draft Plan is initiated with the completion of the Plan by the County and distribution to the aforementioned parties. Presented below is a chronological listing and brief narrative of the required local review steps through County adoptions.



1. Plan Advisory Committee Review – This body has been formed to assist in the development of the Venango County Act 167 Stormwater Management Plan. Municipal members of the Committee have provided input data to the process in the form of storm drainage problem area documentation, storm sewer documentation, proposed solutions to drainage problems, etc. The Committee met on five occasions to review the progress of the Plan. Municipal representatives on the Committee have the responsibility to report on the progress of the Plan to their respective municipalities. Review of the draft Plan by the Plan Advisory Committee will be expedited by the fact that the members are already familiar with the objectives of the Plan, the runoff control strategy employed, and the basic contents of the Plan. The output of the Plan Advisory Committee review will be a revised draft Plan for Municipal and County consideration.
 - a. Municipal Engineers Review – This body has been formed to focus on the technical aspects of the Plan and to educate the Municipal Engineers on the ordinance adoption and implementation requirements of the Plan. The group met twice to solicit input as well as to receive comments and direction in the development of the model ordinance. The result of this is a revised draft model ordinance for Municipal and County consideration.
2. Municipal Review – Act 167 specifies that prior to adoption of the draft Plan by the County, the planning commission and governing body of each municipality in the study area must review the Plan for consistency with other plans and programs affecting the study area. Municipal representatives on the Committee have the responsibility to report on the progress of the Plan to their respective municipalities. Of primary concern during the municipal review would be Venango County's Draft Stormwater Management Model Ordinance that would implement the Plan through municipal adoption. The output of the municipal review will be a letter directed to the County outlining the municipal suggestions, if any, for revising the draft Plan (or Ordinance) prior to adoption by the County.
3. County Review and Adoption – Upon completion of the review by the Plan Advisory Committee, with assistance from the Municipal Engineer focus group, and each municipality, the draft Plan will be submitted to the County Board of Commissioners for their consideration.

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The Venango County review of the draft Plan will include a detailed review by the County Board of Commissioners and an opportunity for public input through the holding of a public hearing. A Public hearing on the draft Plan must be held with a minimum two-week notice period with copies of the draft Plan available for inspection by the general public. Any modifications to the draft Plan would be made by the County based upon input from the public hearings, comments received from the municipalities in the study area, or their own review. Adoption of the draft Plan by Venango County would be by resolution and require an affirmative vote of the majority of the members of the County Board of Commissioners.

The County will then submit the adopted Plan to DEP for their consideration for approval. The review comments of the municipalities will accompany the submission of the adopted Plan to DEP.

IMPLEMENTATION OF THE PLAN

Upon final approval by DEP, each municipality within the county will become responsible for implementation of the Plan. Plan implementation, as used here, is a general term that encompasses the following activities:

- Adoption of municipal ordinances that enable application of the Plan's provisions.
- Review of Drainage Plans for all activities regulated by the Plan and the resulting ordinances.
- Enforcement of the municipal regulations.

Each municipality will need to determine how to best implement the provisions of this Plan within their jurisdiction. Three basic models for Plan implementation are presented in *Table 11.1* below. In some cases it may be advantageous for multiple municipalities to implement the Plan cooperatively, or even on a county-wide basis.

Individual Municipal Model	Each municipality passes, implements, and enforces the SWM ordinance individually.
Multi-Municipal Model	Several municipalities cooperate through a new or existing service-sharing agreement (COG, Sewage Association, etc.)
County Service Provider Model	County department or office (e.g. County Planning Entity or County Conservation District) provides SWM ordinance implementation and enforcement services to municipalities.

Table 11.1. Models for Municipal Plan Implementation

Regardless of what model is used for implementation, each municipality will need to adopt regulations that enable the chosen implementation strategy. For municipalities that choose the Individual Municipal Model, this means municipal adoption of the Model Ordinance or integration of the Plan's provisions into existing municipal regulations. For the other two models, this will require ordinance provisions that designate the regulatory authority and adoption of an inter-municipal agreement or service-sharing agreement.

It is important that the standards and criteria contained in the Plan are implemented correctly, especially if the municipality chooses to integrate the standards and criteria into existing regulations. In either case, it is recommended that the resulting regulatory framework be reviewed by the local planning commission, the municipal solicitor, the Venango County Regional Planning Commission and/or the Venango Conservation District for compliance with the provisions of the Plan and consistency among the various related regulations. Additionally, the adopted regulations may be reviewed by PADEP for compliance with this Plan.

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PROCEDURE FOR UPDATING THE PLAN

Act 167 specifies that the County must review and, if necessary, revise the adopted and approved study area plan every five years, at a minimum. Any proposed revisions to the Plan would require municipal and public review prior to County adoption consistent with the procedures outlined above. An important aspect of the Plan is a procedure to monitor the implementation of the Plan and initiate review and revisions in a timely manner. The process to be used for the Venango County Act 167 Stormwater Management Plan will be as outlined below.

1. Monitoring of the Plan Implementation – The Venango County Regional Planning Commission (VCRPC) will be responsible for monitoring the implementation of the Plan by maintaining a record of all development activities within the study area. Development activities are defined and included in the recommended Municipal Ordinance. Specifically, the VCRPC will monitor the following data records:
 - A. All subdivision and land developments subject to review per the Plan which have been approved within the study area.
 - B. All building permits subject to review per the Plan which have been approved within the study area.
 - C. All DEP permits issued under Chapter 105 (Dams and Waterway Management) and Chapter 106 (Floodplain Management) including location and design capacity (if applicable).
2. Review of Adequacy of Plan - The Plan Advisory Committee will be convened periodically to review the Stormwater Management Plan and determine if the Plan is adequate for minimizing the runoff impacts of new development. At a minimum, the information to be reviewed by the Committee will be as follows:
 - A. Development activity data as monitored by the VCRPC.
 - B. Information regarding additional storm drainage problem areas as provided by the municipal representatives to the Watershed Plan Advisory Committee.
 - C. Zoning amendments within the study area.
 - D. Information associated with any regional detention alternatives implemented within the study area.
 - E. Adequacy of the administrative aspects of regulated activity review.

The Committee will review the above data and make recommendations to the County as to the need for revision to the Venango County Act 167 Stormwater Management Plan. Venango County will review the recommendations of the Plan Advisory Committee and determine if revisions are to be made. A revised Plan would be subject to the same rules of adoption as the original Plan preparation. Should the County determine that no revisions to the Plan are required for a period of five consecutive years, the County will adopt resolutions stating that the Plan has been reviewed and been found satisfactory to meet the requirements of Act 167 and forward the resolution to DEP.

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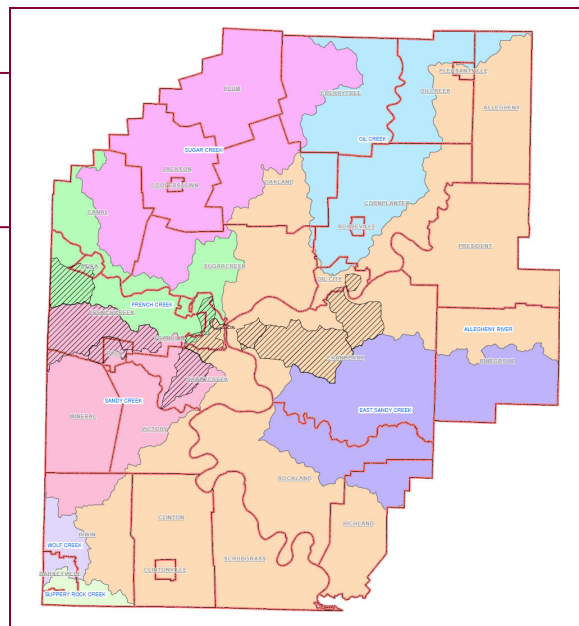
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Appendix A – Watershed Modeling Technical Data

An overview of the process that was used to complete the hydrologic modeling in preparation of this Plan is presented in *Section 6 – Technical Analysis* of this report. The following technical data is included here to supplement the general information provided in that section.

DATA COLLECTION

The GIS data for the hydrologic models was compiled from a variety of sources by county, state, and federal agencies. The data was collected in and processed using GIS software. A description of GIS data collected, the source and its use is provided in *Table A.1*.



Data	Source	Use
3.2-Ft Digital Elevation Model (DEMs)	Venango County Planning	Watershed delineation, length, basin slope, stream slope, average elevation
High Resolution Streamlines	USGS (2008b)	Watershed delineation, cartography, spatial orientation
National Land Cover Dataset – Land Use 2001	USGS (2008c)	Curve number generation for watershed subareas outside of the county boundary.
2010 County Land Use	Venango County Planning	Existing conditions curve number generation
2020 County Land Use	Venango County Planning	Future conditions curve number generation
SURRGO Soils Data	NRCS (2008)	Curve number generation; analysis of infiltration limitations
Carbonate Bedrock	ERRI (1996)	Calculation of percentage of limestone geology within subwatersheds; analysis of infiltration limitations
Storage (percent of lakes, ponds, and wetlands)	USGS (2008d)	Calculation of parameters for USGS Regression Equations
Roadway Data	Venango County Planning	Cartography, spatial orientation

Table A.1. GIS Data Used in Act 167 Technical Analysis

HYDROLOGIC MODEL PARAMETER DATA

SOILS, LAND USE, AND CURVE NUMBERS

The determination of curve numbers is a function of soil type and land use. The hydrologic soil groups were defined by NRCS (2008). The 2001 NLCD was simplified to provide an estimate of curve numbers using the scheme shown in *Table A.2*.

Appendix A – Watershed Modeling Technical Data

GIS Value	NLCD (2001) Description	NRCS (1986) Description	A	B	C	D
11	Open Water	Water	98	98	98	98
21	Developed, Open Space	Open space	39	61	74	80
22	Developed, Low Intensity	Residential - 1 acre	51	68	79	84
23	Developed, Medium Intensity	Residential - 1/2 acre	54	70	80	85
41	Deciduous Forest	Woods	30	55	70	77
42	Evergreen Forest	Woods	30	55	70	77
43	Mixed Forest	Woods	30	55	70	77
52	Shrub/Scrub	Brush	30	48	65	73
71	Grassland/Herbaceous	Meadow	30	58	71	78
81	Pasture/Hay	Pasture	39	61	74	80
82	Cultivated Crops	Contoured Row Crops	65	75	82	86
95	Emergent Herbaceous Wetlands	Water	98	98	98	98
100	Agriculture	Pasture	39	61	74	80
101	Commercial	Commercial and Business	89	92	94	95
102	Community Facility	Open space	39	61	74	80
103	Forested	Woods	30	55	70	77
104	High Density Residential	Residential - 1/8 acre	77	85	90	92
105	Industrial	Industrial	81	88	91	93
106	Industrial/Infrastructure	Industrial	81	88	91	93
107	Low Density Residential	Residential - 1 acre	51	68	79	84
108	Medium Density Residential	Residential - 1/2 acre	54	70	80	85
109	Mixed Residential/Commercial	Residential - 1/8 acre	77	85	90	92
110	Open Space	Open space	39	61	74	80
111	Rural Residential	Residential - 1 acre	51	68	79	84
112	Urban Residential	Residential - 1/8 acre	77	85	90	92
113	Water	Water	98	98	98	98

Table A.2. Curve Number Determination for Venango County for each Hydrologic Soil Group

The curve numbers presented in the above tables represent "average" antecedent runoff condition (i.e. ARC = 2). In a significant hydrologic event, runoff is often influenced by external factors such as extremely dry antecedent runoff conditions (ARC=1) or wet antecedent runoff conditions (ARC=3). The antecedent runoff conditions of the above curve numbers were altered during the calibration process so that model results are within a reasonable range of other hydrologic estimates.

INFILTRATION AND HYDROLOGIC LOSS ESTIMATES

Infiltration and all other hydrologic loss estimates (e.g., evapotranspiration, percolation, depression storage, etc.) taken into account within the HEC-HMS model was consistent with the recharge volume criteria contained in Control Guidance 1 and 2 (CG-1 and CG-2). These losses were modeled in existing conditions as the standard initial abstraction in the NRCS Curve Number Runoff method (i.e., $I_a = 0.2S$). CG1 was simulated by modifying the standard initial abstraction using the following procedure.

Appendix A – Watershed Modeling Technical Data

The runoff volume is computed by HEC-HMS using the following equation:

$$Q_{volume} = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where P = rainfall for a specific storm event (in),

I_a = initial abstraction (in), and

S = maximum retention (in).

S is defined by the following equation which relates runoff volume to curve number:

$$S = \frac{1000}{CN} - 10$$

The standard initial abstraction I_a used in Pennsylvania is typically $0.2S$. HEC-HMS calculates this automatically if no value is entered by the user. This was the approach used for the existing and future conditions modeling scenarios.

In future conditions with implementation of CG-1, the following equation is applicable. The goal of CG-1 is to ensure there is no discharge volume increase for the 2-year storm event, so

$$Q_{CG1} = Q_{Existing} = \frac{(P - I_a)^2}{(P - I_a) + S_{Proposed}}$$

Where P = rainfall for a specific storm event(in),

I_a = initial abstraction (in), and

$S_{Proposed}$ = maximum retention in proposed conditions as a function of the proposed conditions curve number (in).

Assuming $I_a = 0.2S$ as the Initial abstraction is no longer applicable with CG-1 since BMPs are to be installed to control or remove the increase in runoff volume for the 2-year storm. Using the HEC-HMS modeling output for $Q_{Existing}$, the initial abstraction for CG-1 may be calculated using the following equation:

$$I_a = P_{2-year} - \frac{1}{2}(Q_{Existing} \pm \sqrt{Q_{Existing}^2 + 4Q_{Existing}S_{Proposed}}) \text{ for the 2-year event}$$

Thus, the volume control required by CG-1 is implicitly modeled by overriding the HEC-HMS default for initial abstraction with the above value. The qualitative effect of this will be to eliminate the increase in runoff volume for the 2-year storm and to reduce the increase in runoff volume of the more extreme events. Increases in the peak flow values are reduced for all storms, but not eliminated, since the time of concentrations for proposed condition are decreased. Figure C.1 shows the effects of implementing a CG-1 policy on an example watershed. In the first figure representing a 2-year storm event, the hydrograph volumes are exactly the same and the peaks are similar. In the second figure representing a 100-year storm event, the hydrograph

Appendix A – Watershed Modeling Technical Data

volumes are not the same since only the 2-year volume is abstracted; consequently there is still a substantial increase in peak flows, although the CG-1 implementation does reduce the peak flow.

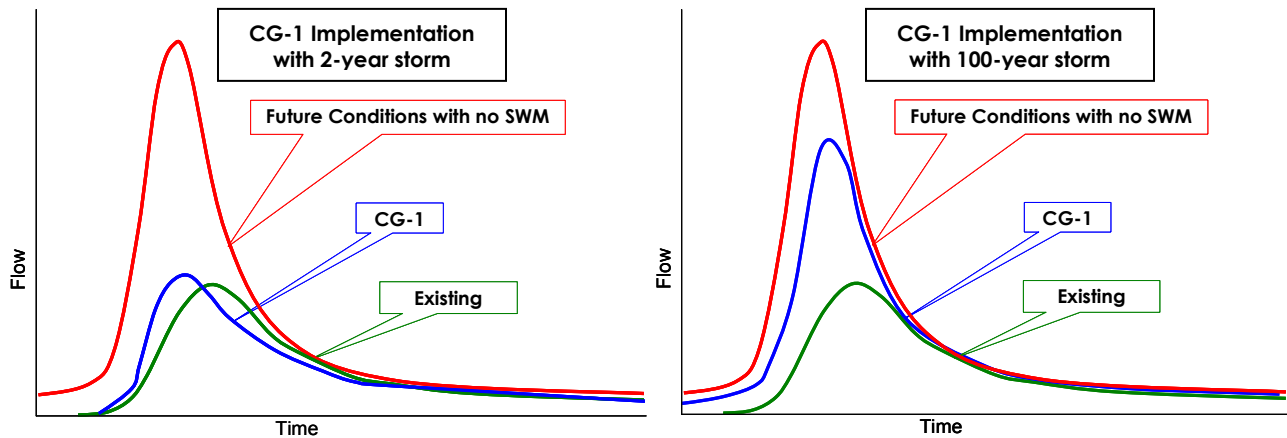


Figure A.1. Typical On-Site Runoff Control Strategy

In the case of this particular sample, release rates might be necessary to prevent increases in peak flow. In situations where there is only a small increase in impervious coverage, however, CG-1 may reduce the proposed conditions peak flow to existing conditions levels without the use of release rates.

For the 2-year event, modeling CG-1 with the above equations results in an increased approximation in initial abstraction represented by D:

$$D = I_a^{CG-1} - 0.2S$$

For the every event of greater magnitude (e.g., 10, 25, 50, and 100-year events), the initial abstraction is calculated using the sum of the traditional method and the increase in initial abstraction for the 2-year event.

$$I_a = 0.2S + D \text{ for all events greater than the 2-year event.}$$

MODEL CALIBRATION

Three parameters were modified to develop a calibrated hydrologic model: the curve number, the time of concentration, and the Manning's coefficient used in the Muskingum-Cunge routing method.

The antecedent runoff condition was altered for each storm event so that each subbasin and calibration point was within an acceptable range of a target flow. The equation used to modify antecedent runoff condition (Maryland Hydrology Panel, 2006):

For $ARC \leq 2$:

Appendix A – Watershed Modeling Technical Data

$$CN_x = \frac{[10 + 5.8(x - 2)]CN_2}{10 + 0.058(x - 2)CN_2}$$

For $ARC > 2$:

$$CN_x = \frac{[10 + 13(x - 2)]CN_2}{10 + 0.013(x - 2)CN_2}$$

Thus a unique ARC and resulting curve number was calculated for each subbasin for each storm event. The same ARC was applied in both existing and proposed conditions. The calibrated and future condition curve numbers for the two watersheds are presented in the Tables at the end of this appendix.

Additionally, lag times were calculated using both TR-55 and the NRCS lag equation. The initial model runs used the results from the NRCS lag equation. A factor between 0 and 2 was applied to the initial value to obtain a calibrated time of concentration value. The same time of concentration was applied to all existing condition storms. The future land use time of concentration was calculated using the NRCS lag equation with future land curve numbers and it was subsequently adjusted by the same factor used in existing conditions.

Finally the Manning's n value for channels and overbank areas was modified to obtain realistic flow values. The respective ranges for the channel and overbank areas were 0.02-0.07 and 0.03-0.2.

MODELING RESULTS

A summary of the hydrologic modeling results has been provided in Section 5 of this Plan. The full modeling results are as presented in the tables at the end of this appendix.

STORMWATER MANAGEMENT DISTRICTS

The regional philosophy used in Act 167 planning introduces a different stormwater management approach than is found in the traditional on-site approach. The difference between the on-site stormwater control philosophy and the Act 167 watershed-level philosophy is the consideration of downstream impacts throughout an individual watershed. The objective of typical on-site design is to control post-development peak flow rates from the site itself; however, a watershed-level design is focused on maintaining existing peak flow rates in the entire drainage basin. The watershed approach requires knowledge of how the site relates to the entire watershed in terms of the timing of peak flows, contribution to peak flows at various downstream locations, and the impact of the additional runoff volume generated by the development of the site. The proposed watershed-level stormwater runoff control philosophy is based on the assumption that runoff volumes will increase with development and the philosophy seeks to manage the increase in volumes such that peak rates of flow throughout the watershed are not increased. The controls implemented in this Plan are aimed at minimizing the increase in runoff volumes and their impacts, especially for the 2-year storm event.

The basic goal of both on-site and watershed-level philosophies is the same, i.e. no increase in the peak rate of stream flow. The end products, however, can be very different as illustrated in the following simplified example.

Presented in *Figure A.2* is a typical on-site runoff control strategy for dealing with the increase in the peak rate of runoff with development. The Existing Condition curve represents the pre-

Appendix A – Watershed Modeling Technical Data

development runoff hydrograph. The Developed Condition hydrograph illustrates three important changes in the site runoff response with development:

1. A higher peak rate,
2. A faster occurring peak (shorter time for the peak rate to occur), and
3. An increase in total runoff volume

The "Controlled" Developed Condition hydrograph is based on limiting the post-development runoff peak rate to the pre-development level through use of detention facilities; but the volume is still increased. The impact of "squashing" the post-development runoff to the pre-development peak without reducing the volume is that the peak rate occurs over a much longer period of time. The instantaneous pre-development peak has become an extended peak (approximately two (2) hours long in this example) under the "Controlled" Developed Condition.

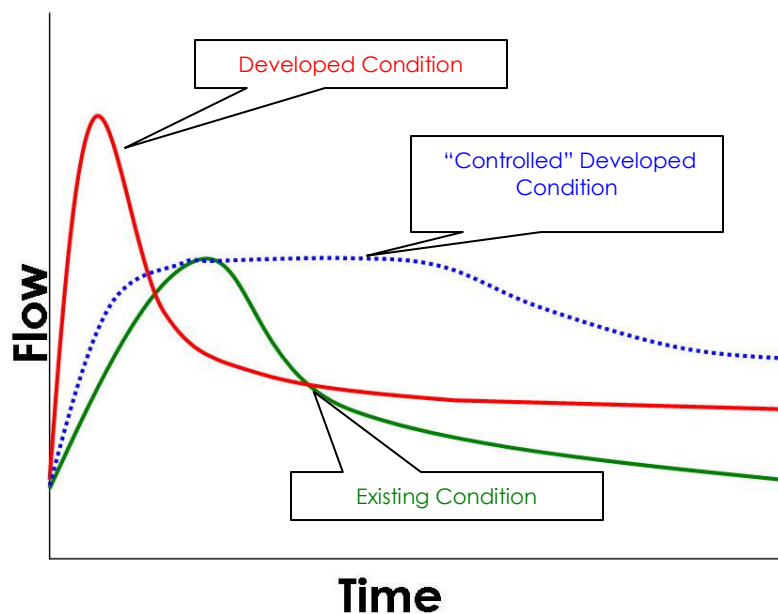


Figure A.2. Typical On-Site Runoff Control Strategy

Considering the outflow from the site only, the maintenance of the pre-development peak rate of runoff is an effective management approach. However, *Figures A.3 and A.4* illustrate the potential detrimental impact of this approach. *Figure A.3* represents the existing hydrograph at the point of confluence of Watershed A and Watershed B. The timing relationship of the watersheds is that Watershed A peaks more quickly (at time T_{pA}) than the Total Hydrograph, while Watershed B peaks later (at time T_{pB}), than the Total Hydrograph, resulting in a combined time to peak approximately in the middle (at time T_p). Watershed A is an area of significant development pressure, and all new development proposals are met with the on-site runoff control philosophy as depicted in *Figure A.2*. The eventual end product of the Watershed A development under the "Controlled" Development Condition is an extended peak rate of runoff as shown in *Figure A.4*. The extended Watershed A peak occurs long enough so that it coincides with the peak of Watershed B. Since the Total Hydrograph at the confluence is the summation of Watershed A and Watershed B, the Total Hydrograph peak is increased under these conditions to the "Controlled" Total Hydrograph. The conclusion from the example is that simply controlling

Appendix A – Watershed Modeling Technical Data

peak rates of runoff on-site does not guarantee an effective watershed level of control because of the increase in total runoff volume. The net result is that downstream peaks can increase and extend for longer durations.

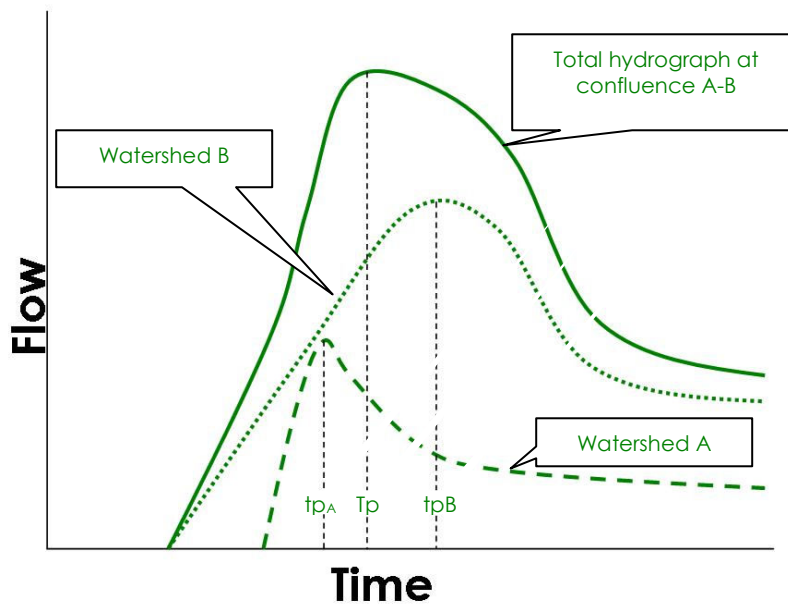


Figure A.3. Existing Hydrograph (Pre-Development)

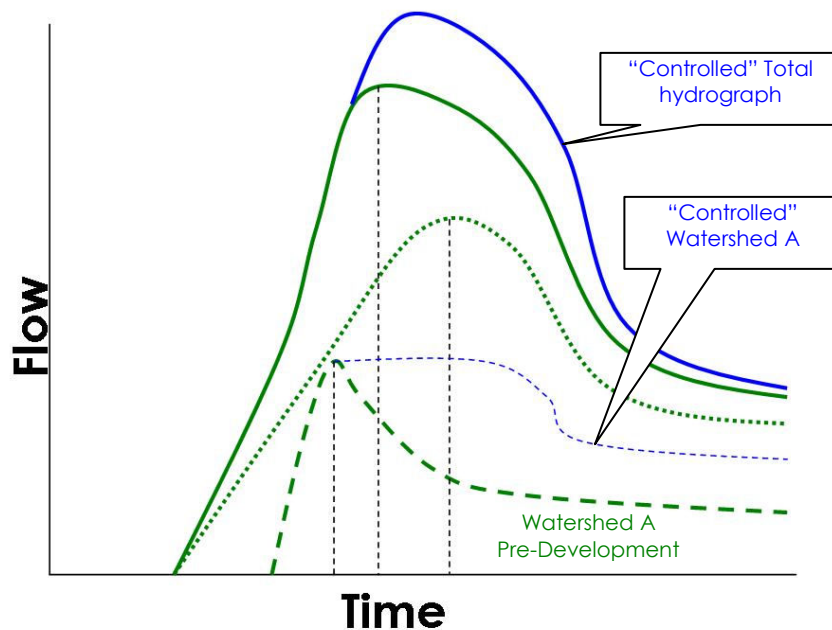


Figure A.4. Controlled Runoff Condition (Post-Development)

Appendix A – Watershed Modeling Technical Data

RELEASE RATE CONCEPT

The previous example indicated that, in certain circumstances, it is not enough to control post-development runoff peaks to pre-development levels if the overall goal is no increase in peak runoff at any point in the watershed. The reasons for this potential increase are how the various parts of the watershed interact, in time, with one another and the increased rate and volume of runoff associated with development and increases in impervious surfaces. The critical runoff criteria for a given site or watershed area is not necessarily its own pre-development peak rate of runoff but rather the pre-development contribution of the site or watershed area to the peak flow at a given point of interest.

To account for increases of volume and peak flow resulting from the combination of these post-development hydrographs, stormwater management districts have been assigned to various areas within the county boundary that have more restrictive release rates than the conventional 100% release rate. As shown in Plate 10, some areas within specific watersheds have reduced release rates where CG-1 may be difficult to completely implement.

The specification of a 100% release rate as a performance standard would represent the conventional approach to runoff control philosophy, namely controlling the post-development peak runoff to pre-development levels. This is a well-established and technically feasible control that is effective at-site and, where appropriate, would be an effective watershed-level control.

It is important to acknowledge that there are several problems with the release rate concept. One of the problems is that some areas can reach unreasonably low release rates. This can be seen in the release rate equation, which dictates that sub-watersheds that peak farther away from the entire watershed will have a lower release rate. Indeed, sub-watersheds whose runoff drains almost completely before or after the watershed peak will approach a release rate of zero (because the numerator approaches zero).

Another problem is that release rates are highly dependent on, and sensitive to, the timing of hydrographs. Since natural storms follow a different timing than design storms, it is still possible that watershed wide controls designed with release rates only, will encounter increased runoff problems. This is because the runoff rates are still much higher in the developed condition, and increased volumes over an extended time can combine to increase peak flow rates. Similar to the traditional on-site detention pond, release rates are purely a peak “rate” type of control.

Patterns of development may also determine how effective designs are that use only release rates, or any control based on timing. This is because rates based on timing assume a certain development and rainfall patterns, and the model uses uniform parameters across a sub-watershed. In reality, the actual development and rainfall patterns can be highly variable across a sub-watershed and can be quite different than the “Future Full Build Out” land use scenario used in the planning study. This uncertainty can affect any type of control, but controls based on timing alone are especially sensitive to these parameters. Some controls, such as volume controls, are less sensitive since they remove a certain amount of runoff from the storm event wherever development occurs. In a sense, volume controls tend to more closely simulate what occurs in a natural system.

Combining volume controls with peak rate controls, as proposed in this plan, will be more effective than having only peak rate controls. Volume controls have several advantages such as:

Appendix A – Watershed Modeling Technical Data

1. Increased runoff volume may infiltrate and provide recharge to existing groundwater supplies. This may not happen with rate controls since all of the runoff excess is discharged in a relatively short time frame.
2. Volume controls tend to mimic natural systems (i.e., excess runoff volume is infiltrated) and thus are more effective in controlling natural storms since they are not highly sensitive to timing issues.
3. Volume controls often have enhanced water quality benefits.

The Design Storm Method and The Simplified Method as implemented in this Plan, provide the benefits described above.

SUMMARY MODEL OUTPUT

- Hydrologic Parameters for Venango County HEC-HMS Models
- Hydrologic Results for Venango County HEC-HMS Models
- Calibration Results for Detailed HEC-HMS Models with 2010 Land Use

Hydrologic Parameters for Venango County HEC-HMS Models

Subwatershed Name	Subbasin	Drainage Area (mi ²)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
E003	E003	0.66	71.6	30.7	71.8	30.5
F088	F88	1.33	69.9	43.7	72.8	40.4
F089	F89	0.16	56.9	54.4	64.2	45.1
Halls Run	W0100	1.07	70.5	84.1	70.5	84.1
	W0102	0.84	76.3	62.2	76.3	62.2
	W0104	0.82	75.4	63.9	76.8	61.3
	W0106	0.97	70.4	49.2	70.4	49.2
	W0108	1.45	75.0	52.3	75.0	52.3
	W0110	1.32	67.7	68.8	67.7	68.8
	W0112	1.07	68.2	62.8	68.2	62.8
	W0114	0.89	67.3	64.1	67.3	64.1
	W0116	0.11	71.1	24.2	71.1	24.2
	W0118	1.11	68.8	55.2	69.9	53.6
	W0120	1.24	71.1	52.5	72.8	50.1
	W0122	0.47	63.8	43.4	63.8	43.4
Little Sandy Creek	W0200	1.09	76.3	48.5	76.3	48.5
	W0202	1.55	77.3	57.1	77.3	57.1
	W0204	1.56	78.4	59.5	78.4	59.5
	W0206	1.29	68.5	54.9	68.5	54.9
	W0208	1.69	73.0	67.1	73.0	67.1
	W0210	0.99	72.4	44.8	72.4	44.8
	W0212	1.75	68.6	65.4	68.6	65.4
	W0214	1.75	78.7	64.1	78.7	64.1
	W0216	1.08	78.0	50.1	78.0	50.1
	W0218	1.15	77.9	46.1	77.9	46.1
	W0220	0.26	75.3	26.4	75.3	26.4
	W0222	0.73	71.9	41.9	71.9	41.9
	W0224	1.55	72.1	60.7	72.1	60.7
	W0226	1.25	69.5	50.8	69.8	50.5
	W0228	0.54	68.7	46.3	68.8	46.3
	W0230	1.36	71.3	51.2	71.5	50.9
	W0232	0.03	64.8	17.1	64.8	17.1
	W0234	2.21	71.8	47.1	75.2	42.9
Lower Twomile Run	W0300	2.07	70.6	90.1	70.6	90.1
	W0302	0.90	69.8	43.7	75.5	37.2
	W0304	1.67	78.6	66.4	78.9	65.9
	W0306	2.11	69.0	80.0	69.4	79.2
	W0308	2.05	64.5	68.0	67.1	63.4
	W0310	2.56	63.5	84.5	71.3	68.7
	W0312	0.57	58.8	35.0	59.5	34.4
Mill Creek	W0400	1.40	77.8	67.5	77.8	67.5
	W04010	1.94	70.4	80.7	70.4	80.7
	W0402	1.01	74.2	50.9	74.2	50.9
	W0404	0.91	73.4	52.9	73.4	52.9

Hydrologic Parameters for Venango County HEC-HMS Models

Subwatershed Name	Subbasin	Drainage Area (mi ²)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Mill Creek	W0406	2.16	79.7	98.9	79.7	98.9
	W0408	2.18	77.9	76.1	77.9	76.1
	W0412	1.81	74.3	57.4	74.3	57.4
	W0414	1.17	69.5	60.4	69.5	60.4
	W0416	1.24	64.1	66.0	64.1	66.0
	W0418	1.53	64.9	75.8	64.9	75.8
Morrison Run	W0500	1.00	73.9	59.4	73.9	59.4
	W0502	1.30	76.2	57.1	81.0	49.4
	W0504	1.64	64.5	64.1	67.8	58.7
P004	P004	1.23	63.3	18.7	68.8	16.2
P059	P59	0.89	72.0	50.7	72.9	49.4
P60	P60	0.38	72.9	10.5	72.9	10.5
P091	P91	0.08	56.4	44.0	63.1	37.1
Sage Run	W0600	1.91	72.1	68.9	75.0	63.5
	W0602	2.00	71.9	73.9	73.0	71.7
	W0604	0.61	61.8	44.2	70.2	35.5
	W0606	0.91	66.0	42.3	70.0	38.0

Hydrologic Parameters for Venango County HEC-HMS Models

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
E003	E003	71.6	68.8	67.1	65.6	64.1	62.7
F088	F88	69.9	67.1	65.3	63.8	62.2	60.9
F089	F89	56.9	53.5	51.6	50.0	48.3	46.8
Halls Run	W0100	70.5	70.5	69.5	68.4	67.1	66.2
	W0102	76.3	74.7	72.8	71.4	69.9	68.7
	W0104	75.4	73.7	71.7	70.4	68.8	67.6
	W0106	70.4	68.5	66.4	64.9	63.2	61.9
	W0108	75.0	67.7	65.4	63.9	62.2	60.9
	W0110	67.7	66.2	62.2	59.9	57.3	55.2
	W0112	68.2	68.8	66.8	65.4	64.0	62.6
	W0114	67.3	65.3	63.0	61.4	59.7	58.3
	W0116	71.1	69.2	67.1	65.6	64.0	62.6
	W0118	68.8	68.2	66.0	64.5	62.9	61.6
	W0120	71.1	68.0	65.9	64.4	62.8	61.6
	W0122	63.8	61.7	59.4	57.7	56.0	54.6
Little Sandy Creek	W0200	76.3	67.9	65.9	63.9	61.7	59.1
	W0202	77.3	68.3	66.2	64.3	62.2	60.4
	W0204	78.4	68.5	66.5	64.6	62.5	60.3
	W0206	68.5	68.0	65.7	64.1	62.4	61.1
	W0208	73.0	68.9	66.9	65.5	64.0	62.7
	W0210	72.4	66.7	64.5	63.0	61.4	60.1
	W0212	68.6	68.9	66.9	65.4	63.9	62.5
	W0214	78.7	68.9	66.9	65.2	63.3	61.8
	W0216	78.0	68.3	66.5	64.7	62.7	60.9
	W0218	77.9	67.4	64.9	63.0	61.0	60.0
	W0220	75.3	69.9	67.8	66.4	64.9	63.7
	W0222	71.9	66.2	63.9	62.5	60.8	59.5
	W0224	72.1	68.6	66.5	65.1	63.6	62.4
	W0226	69.5	67.8	65.7	64.1	62.4	61.2
	W0228	68.7	62.6	60.3	58.8	57.1	55.8
	W0230	71.3	68.0	65.8	64.4	62.9	61.7
	W0232	64.8	58.4	56.1	54.5	52.8	51.4
	W0234	71.8	67.3	64.6	63.1	61.4	60.0
Lower Twomile Run	W0300	70.6	70.1	68.7	67.0	65.2	63.9
	W0302	69.8	69.6	68.3	67.3	66.1	64.9
	W0304	78.6	69.2	67.7	65.8	63.7	62.6
	W0306	69.0	69.6	67.6	65.8	63.8	62.6
	W0308	64.5	68.2	66.2	63.7	62.1	60.6
	W0310	63.5	69.1	67.8	65.6	63.4	62.4
	W0312	58.8	65.1	62.2	59.2	57.5	55.7
Mill Creek	W0400	77.8	69.6	68.2	67.1	65.8	64.8
	W04010	70.4	69.7	68.2	66.8	65.3	64.3
	W0402	74.2	68.1	66.0	64.7	63.3	61.9
	W0404	73.4	69.8	68.4	67.3	66.2	65.1

Hydrologic Parameters for Venango County HEC-HMS Models

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Mill Creek	W0406	79.7	71.2	70.6	69.6	68.5	67.5
	W0408	77.9	69.5	67.9	66.6	65.1	64.1
	W0412	74.3	68.1	65.9	64.4	62.7	61.5
	W0414	69.5	68.7	66.7	65.4	63.9	62.6
	W0416	64.1	68.8	67.1	65.7	64.1	62.9
	W0418	64.9	69.5	68.1	66.7	65.1	63.9
Morrison Run	W0500	73.9	71.3	69.9	68.6	67.1	65.8
	W0502	76.2	68.4	65.4	63.8	62.2	59.9
	W0504	64.5	68.0	65.3	63.1	61.1	59.1
P004	P004	63.3	60.1	58.2	56.6	55.0	53.5
P059	P59	72.0	69.2	67.5	66.1	64.6	63.2
P60	P60	72.9	70.2	68.5	67.1	65.6	64.3
P091	P91	56.4	53.1	51.1	49.5	47.8	46.4
Sage Run	W0600	72.1	68.8	66.8	65.4	63.8	62.5
	W0602	71.9	69.0	67.2	65.8	64.3	63.1
	W0604	61.8	58.3	56.2	54.6	52.9	51.6
	W0606	66.0	62.6	60.5	59.0	57.3	56.0

Hydrologic Parameters for Venango County HEC-HMS Models

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
E003	E003	71.8	69.0	67.3	65.9	64.3	63.0
F088	F88	72.8	70.1	68.4	67.0	65.5	64.2
F089	F89	64.2	61.1	59.2	57.6	56.0	54.5
Halls Run	W0100	70.5	70.5	69.5	68.4	67.1	66.2
	W0102	76.3	74.7	72.8	71.4	69.9	68.7
	W0104	76.8	75.2	73.3	72.0	70.5	69.3
	W0106	70.4	68.5	66.4	64.9	63.2	61.9
	W0108	75.0	67.7	65.4	63.9	62.2	60.9
	W0110	67.7	66.2	62.2	59.9	57.3	55.2
	W0112	68.2	68.8	66.8	65.4	64.0	62.6
	W0114	67.3	65.3	63.0	61.4	59.7	58.3
	W0116	71.1	69.2	67.1	65.6	64.0	62.6
	W0118	69.9	69.3	67.1	65.7	64.1	62.9
	W0120	72.8	69.8	67.7	66.3	64.7	63.5
	W0122	63.8	61.7	59.4	57.7	56.0	54.6
Little Sandy Creek	W0200	76.3	67.9	65.9	63.9	61.7	59.1
	W0202	77.3	68.3	66.2	64.3	62.2	60.4
	W0204	78.4	68.5	66.5	64.6	62.5	60.3
	W0206	68.5	68.0	65.7	64.1	62.4	61.1
	W0208	73.0	68.9	66.9	65.5	64.0	62.7
	W0210	72.4	66.7	64.5	63.0	61.4	60.1
	W0212	68.6	68.9	66.9	65.4	63.9	62.5
	W0214	78.7	68.9	66.9	65.2	63.3	61.8
	W0216	78.0	68.3	66.5	64.7	62.7	60.9
	W0218	77.9	67.4	64.9	63.0	61.0	60.0
	W0220	75.3	69.9	67.8	66.4	64.9	63.7
	W0222	71.9	66.2	63.9	62.5	60.8	59.5
	W0224	72.1	68.6	66.5	65.1	63.6	62.4
	W0226	69.8	68.1	65.9	64.3	62.7	61.5
	W0228	68.8	62.7	60.4	58.8	57.2	55.9
	W0230	71.5	68.2	66.0	64.6	63.1	61.8
	W0232	64.8	58.4	56.1	54.5	52.8	51.4
	W0234	75.2	71.0	68.4	67.0	65.3	64.0
Lower Twomile Run	W0300	70.6	70.1	68.7	67.0	65.2	63.9
	W0302	75.5	75.4	74.3	73.3	72.3	71.2
	W0304	78.9	69.5	68.1	66.2	64.1	62.9
	W0306	69.4	69.9	68.0	66.2	64.2	63.0
	W0308	67.1	70.7	68.8	66.4	64.8	63.4
	W0310	71.3	76.2	75.0	73.2	71.2	70.3
	W0312	59.5	65.8	62.9	60.0	58.2	56.5
Mill Creek	W0400	77.8	69.6	68.2	67.1	65.8	64.8
	W04010	70.4	69.7	68.2	66.8	65.3	64.3
	W0402	74.2	68.1	66.0	64.7	63.3	61.9
	W0404	73.4	69.8	68.4	67.3	66.2	65.1

Hydrologic Parameters for Venango County HEC-HMS Models

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Mill Creek	W0406	79.7	71.2	70.6	69.6	68.5	67.5
	W0408	77.9	69.5	67.9	66.6	65.1	64.1
	W0412	74.3	68.1	65.9	64.4	62.7	61.5
	W0414	69.5	68.7	66.7	65.4	63.9	62.6
	W0416	64.1	68.8	67.1	65.7	64.1	62.9
	W0418	64.9	69.5	68.1	66.7	65.1	63.9
Morrison Run	W0500	73.9	71.3	69.9	68.6	67.1	65.8
	W0502	81.0	74.2	71.4	70.1	68.6	66.5
	W0504	67.8	71.1	68.6	66.5	64.6	62.7
P004	P004	68.8	65.9	64.1	62.6	61.0	59.6
P059	P59	72.9	70.2	68.5	67.1	65.6	64.3
P60	P60	72.9	70.2	68.5	67.1	65.6	64.3
P091	P91	63.1	59.9	58.0	56.4	54.8	53.3
Sage Run	W0600	75.0	71.9	70.0	68.6	67.1	65.9
	W0602	73.0	70.2	68.4	67.1	65.6	64.4
	W0604	70.2	67.1	65.1	63.6	62.0	60.8
	W0606	70.0	66.9	64.9	63.4	61.8	60.6

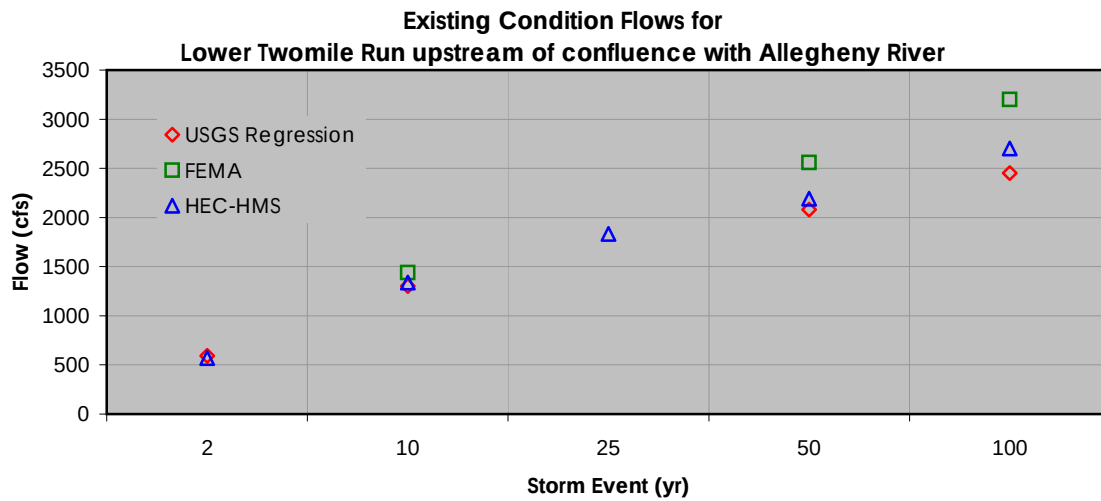
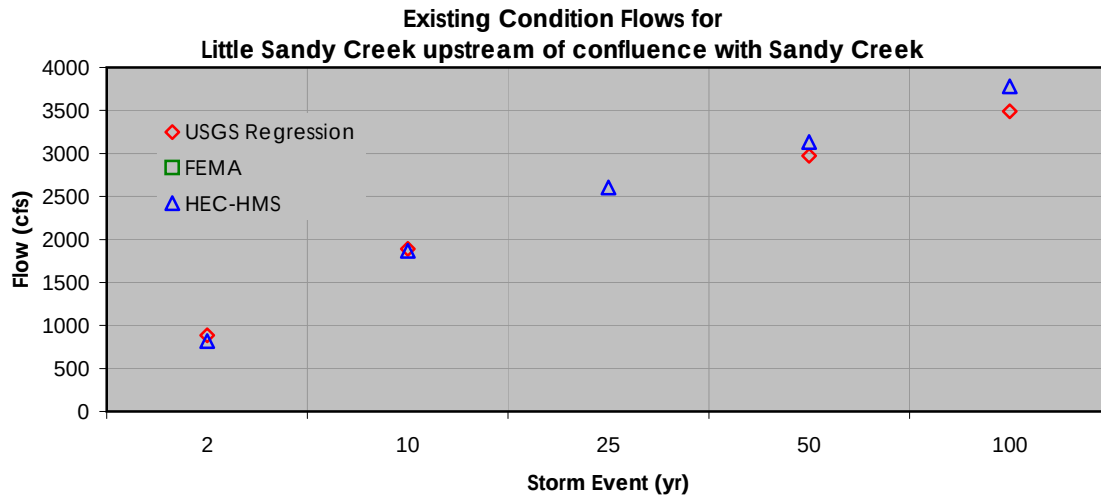
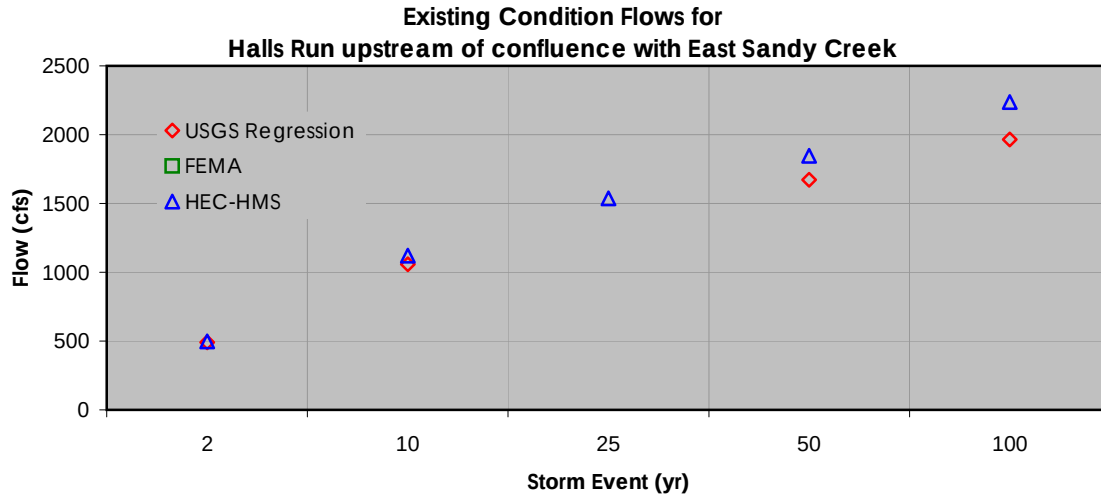
Hydrologic Results for Venango County HEC-HMS Models

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi ²)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	J44	1436360.0	458190.4	3.91	245	586	825	1,001	1,218	322	721	995	1,197	1,443
2	P32	1434792.0	459870.4	4.52	253	615	870	1,059	1,293	348	783	1,082	1,302	1,572
3	Outlet_SageRun	1434014.4	463921.6	5.43	274	668	949	1,157	1,416	381	859	1,190	1,434	1,735
4	J35	1389028.8	438212.8	2.30	182	415	581	703	823	272	563	767	916	1,063
5	Outlet_MorrisonRun	1386404.8	430046.4	3.94	271	618	859	1,037	1,229	402	842	1,152	1,381	1,610
6	J107	1327857.6	462280.0	2.16	138	331	459	560	676	138	331	459	560	676
7	J46	1335336.0	464088.0	5.74	290	658	924	1,136	1,393	290	658	924	1,136	1,393
8	J109	1343003.2	464894.4	7.68	378	893	1,254	1,527	1,863	378	893	1,254	1,527	1,863
9	J108	1349953.6	466536.0	9.49	427	1,008	1,420	1,734	2,122	427	1,008	1,420	1,734	2,122
10	J51	1354232.0	466648.0	11.67	496	1,136	1,606	1,967	2,412	496	1,136	1,606	1,967	2,412
11	J56	1359329.6	467115.2	13.82	569	1,289	1,797	2,197	2,699	569	1,289	1,797	2,197	2,699
12	Outlet_Mill_Creek	1365089.6	469419.2	15.35	623	1,409	1,957	2,381	2,915	623	1,409	1,957	2,381	2,915
13	J106	1428561.6	440824.0	1.67	114	280	380	444	543	119	289	391	457	557
14	J44	1436360.0	458190.4	3.91	245	586	825	1,001	1,218	322	721	995	1,197	1,443
15	E01	1417044.8	447454.4	7.90	432	1,016	1,386	1,648	2,015	456	1,057	1,437	1,706	2,084
16	J47	1408196.8	448472.0	11.36	544	1,282	1,762	2,103	2,594	615	1,387	1,893	2,256	2,763
17	Outlet_LowerTwoMileRun	1408774.4	442030.4	13.07	571	1,337	1,834	2,192	2,704	644	1,445	1,970	2,350	2,879
18	J114	1351115.2	445617.6	3.11	211	513	706	831	972	211	513	706	831	972
19	J104	1342296.0	458129.6	1.75	118	282	390	464	556	118	282	390	464	556
20	J103	1345966.4	455374.4	2.83	170	405	562	669	819	170	405	562	669	819
21	J102	1349128.0	453848.0	3.98	211	499	700	838	1,035	211	499	700	838	1,035
22	J137	1351745.6	452584.0	5.33	262	606	850	1,020	1,241	262	606	850	1,020	1,241
23	J124	1355320.0	450072.0	10.46	530	1,273	1,772	2,105	2,511	530	1,273	1,772	2,105	2,511
24	J105	1360286.4	449460.8	12.01	590	1,408	1,968	2,350	2,816	590	1,408	1,968	2,350	2,816
25	J127	1364900.8	451745.6	14.95	680	1,601	2,242	2,689	3,236	681	1,602	2,242	2,690	3,237
26	J134	1367396.8	452507.2	16.48	708	1,659	2,322	2,789	3,359	709	1,660	2,323	2,789	3,360
27	J121	1373556.8	448657.6	19.59	779	1,798	2,512	3,022	3,645	780	1,799	2,513	3,023	3,646
28	P72	1373464.0	447678.4	19.62	777	1,789	2,497	3,003	3,621	778	1,790	2,499	3,004	3,622
29	Outlet_LittleSandyCreek	1371745.6	445224.0	21.83	818	1,868	2,606	3,134	3,779	827	1,880	2,619	3,148	3,795
30	J42	1449323.2	444539.2	1.45	97	238	341	415	508	97	238	341	415	508
31	J41	1445016.0	441611.2	2.77	150	346	490	595	729	150	346	490	595	729
32	J69	1440769.6	441057.6	4.91	251	568	817	1,003	1,250	251	568	817	1,003	1,250
33	J64	1437012.8	438859.2	6.64	318	696	994	1,225	1,531	318	696	994	1,225	1,531
34	J59	1435092.8	437681.6	7.57	362	793	1,099	1,354	1,694	364	801	1,104	1,356	1,697

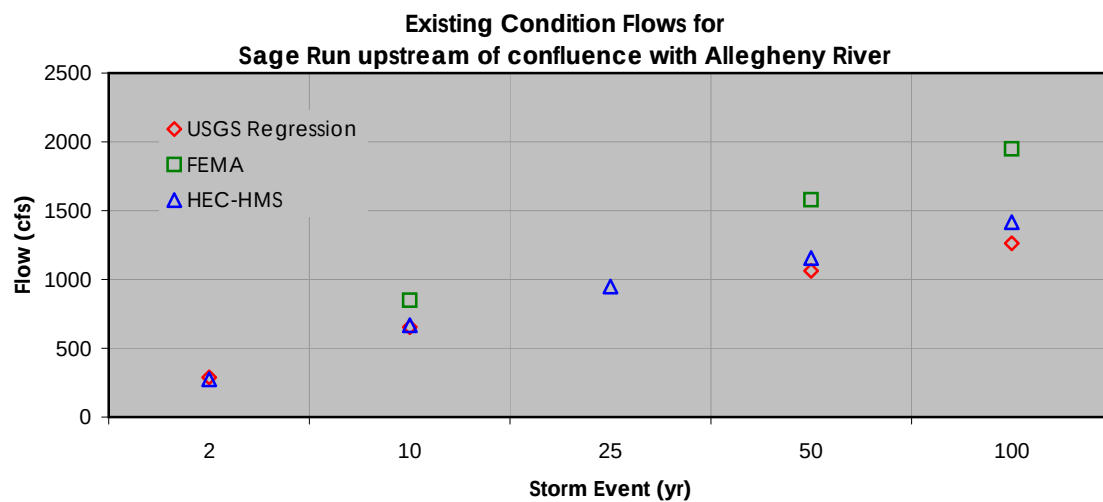
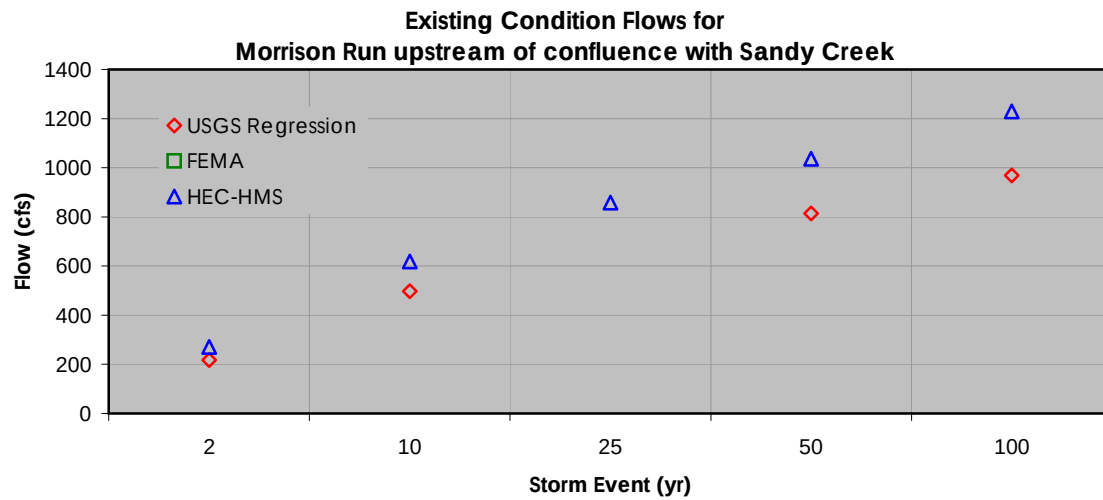
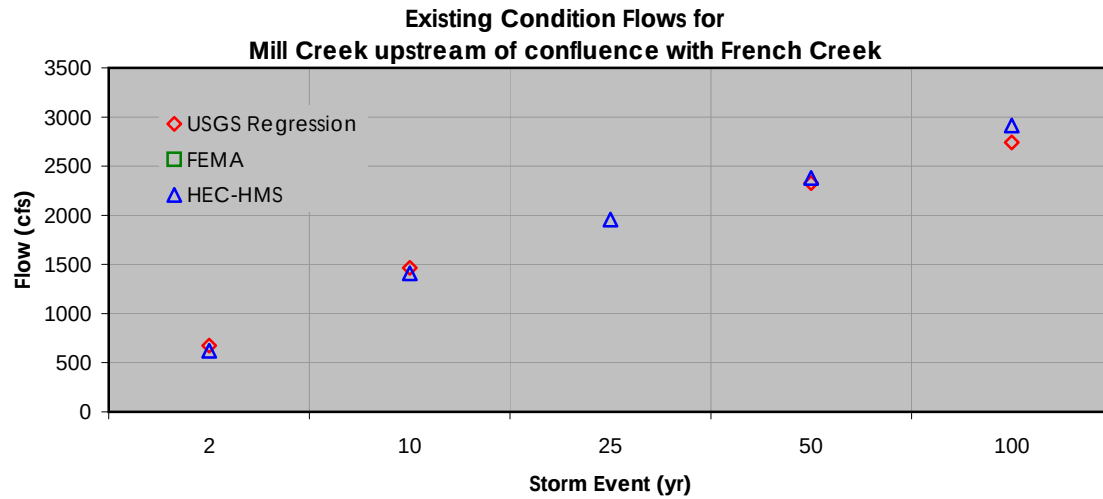
Hydrologic Results for Venango County HEC-HMS Models

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi ²)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
35	J43	1433691.2	434760.0	8.68	406	904	1,252	1,507	1,826	416	921	1,271	1,529	1,843
36	J54	1431528.0	428638.4	10.89	490	1,097	1,505	1,809	2,193	514	1,144	1,559	1,867	2,251
37	Outlet_HallsRun	1428984.0	426155.2	11.36	498	1,120	1,537	1,847	2,238	523	1,167	1,593	1,908	2,301
38	E003	1435052.1	464282.6	0.66	73	185	262	318	384	75	189	267	325	392
39	F088	1398648.0	448824.0	1.33	92	246	356	436	531	143	340	474	573	688
40	F089	1399035.2	451665.6	0.16	1	4	8	11	14	4	15	24	31	39
41	P004	1426214.4	459464.8	1.23	36	185	306	396	507	138	413	607	748	915
42	P059	1397406.9	458119.0	0.89	74	179	252	306	369	84	198	276	333	399
43	P060	1380620.8	473475.1	0.38	104	242	333	400	478	104	242	333	400	478
44	P091	1395873.2	459400.5	0.08	0	2	4	6	8	2	7	12	16	20

Calibration Results for Venango County HEC-HMS Models

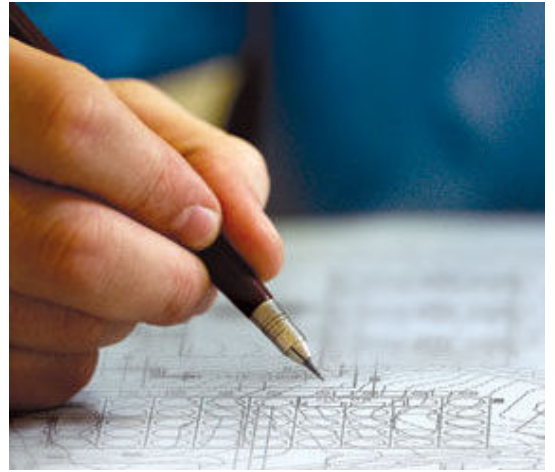


Calibration Results for Venango County HEC-HMS Models



Appendix B – Supporting Calculations for the Design Example

The *Model Ordinance* has been developed to implement a variety of control standards in order to achieve a holistic approach to stormwater management. The overall design process has been addressed in *Section VIII* of this Plan. The following example calculations have been provided to further clarify the design method. These calculations parallel the calculations that are made on the worksheets provided in the *Pennsylvania Stormwater Best Management Practices Manual* (PA BMP Manual) a copy of which are provided at the back of this appendix.



SUPPORTING CALCULATIONS - DESIGN EXAMPLE 1

NON-STRUCTURAL BMP CREDITS

Protect Sensitive Natural Resources

(Refer to Worksheet 2 & Worksheet 3)

$$\begin{aligned}\text{Stormwater Management Area} &= \text{Total Drainage Area} - \text{Protected Area} \\ &= 9.78 - 1.31 (\text{woods}) - 0.37 (\text{minimum disturbance}) \\ &= \mathbf{8.1\text{-Acres}}\end{aligned}$$

This is the total area used for pre-development and post-development volume calculations.

Minimum Soil Compaction

(Refer to Worksheet 3)

Lawn Area (post development) protected from compaction = 16,165-ft²

$$16,165\text{-ft}^2 \times 1/4" \times 1/12 = \mathbf{337\text{-ft}^3}$$

To be eligible for this credit, areas must not be compacted during construction and be guaranteed to remain protected from compaction. Minimum soil compaction credits for lawn area (Open Space) are applicable for this example because specific measures were utilized to protect the back yard lawn areas of Lots 9 & 10 and this area has been placed in a permanent minimum soil compaction easement. Credits for the meadow area can be applied for areas that are not disturbed during construction and will remain in pre-development vegetated cover condition.

Disconnect Non-Roof Impervious to Vegetated Areas

(Refer to Worksheet 3)

$$\begin{aligned}\text{Lot Impervious Area} &= 10 (\text{Lots}) \times 1,000 (\text{ft}^2/\text{lot}) = 10,000\text{-ft}^2. \\ 10,000\text{-ft}^2 \times 1/3" \times 1/12 &= \mathbf{278\text{-ft}^3}\end{aligned}$$

This credit is applied for the impervious surfaces (driveways and sidewalks) which direct runoff to vegetated surfaces and not directly into a stormwater collection system. The 1/3" credit is used because runoff discharges across the lawn area and is received by rain gardens, which

Appendix B – Supporting Calculations for the Design Example

are structures specifically placed to receive and infiltrate runoff. The 1/4" credit would be used for runoff not discharged to a specific infiltration structure or an area that has been protected from soil compaction.

Summation of Non-Structural BMP Credits

$$= 337\text{-ft}^3 + 278\text{-ft}^3 = \mathbf{615\text{-ft}^3}$$

CHANGE IN RUNOFF VOLUME FOR THE 2-YEAR STORM EVENT

(Refer to *Worksheet 4*)

2-year, 24-hour Rainfall Depth = 2.76"

Pre-Development 2-yr Runoff Volume = 5,682 ft³

Post-Development 2-yr Runoff Volume = 18,281 ft³

Change in Runoff Volume for the 2-year, 24-hour storm event:

$$= 18,281\text{-ft}^3 - 5,682\text{-ft}^3 = \mathbf{12,599\text{-ft}^3}$$

This is the volume that must be managed through a combination of non-structural BMP credits and structural BMP credits.

25% LIMIT FOR NON-STRUCTURAL BMP CREDITS

(Refer to *Worksheet 5*)

*Per Chapter 8 of the Pennsylvania Stormwater BMP Manual, Non-Structural Credits may be **no greater than 25%** of the total required control volume.*

Check 25% Non-Structural Credit Limit:

$$= 615\text{-ft}^3 / 12,599\text{-ft}^3 = \mathbf{4.9\%}$$

Calculated credits are under the allowable 25% limit for non-structural credits.

STRUCTURAL CONTROL VOLUME REQUIREMENT

(Refer to *Worksheet 5*)

Required Structural BMP infiltration volume:

$$\begin{aligned} &= \text{Change in Runoff Volume} - \text{Non-Structural BMP Credits} \\ &= 12,599\text{-ft}^3 - 615\text{-ft}^3 = \mathbf{11,984\text{-ft}^3} \end{aligned}$$

STRUCTURAL BMP VOLUME CREDITS

The sizing of structural infiltration BMPs is based on two primary criteria:

1. Maximum loading ratios – There are two different loading ratios that are important when determining the size of a structural BMP. These ratios are derived from guidelines found in the *Pennsylvania Stormwater BMP Manual*.
 - a. Maximum loading ratio of Impervious Area to Infiltration Area = 5:1
 - b. Maximum loading ratio of Total Drainage Area to Infiltration Area = 8:1

Appendix B – Supporting Calculations for the Design Example

2. Expected runoff volume loading – Structural BMPs must be sized to accommodate the runoff volume they are expected to receive from the contributing drainage area. Some of this volume will be removed and the remainder must be safely conveyed through an overflow device. The removed volume, or infiltration volume, is the important component for sizing the infiltration BMP. A good starting point for infiltration volume is to calculate the contributing area runoff volume for the 2-year, 24-hour design storm. This volume may not be suitable for a particular site design, but starting with this volume will usually result in a design that is close to what is appropriate, and it can be adjusted as necessary. Additional design restrictions may exist for certain BMPs, so these should be considered prior to using this sizing method.

Dry Wells

(Example calculations shown for Lot #1; Refer to *Worksheet 5A* for additional calculations)

Surface Area:

Find the minimum dry well surface area for each lot based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)

Tributary impervious area = 2,150-ft² (typ.)

= 2,150-ft² / 5 = **430-ft²**

= minimum surface area of dry well per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1

Total drainage area = 2,590-ft² (typ.)

= 2,590-ft² / 8 = **324-ft²**

= minimum surface area of dry well per pervious loading ratio

The larger of the two calculated areas is the total minimum surface area required for each lot. An individual dry well is placed at each of the four major corners of the house to promote distribution of impervious area runoff. However, the total surface area is used throughout the remaining volume credit calculations for simplicity. The surface area of each dry well is calculated below:

Total Minimum Dry Well Surface Area ÷ Number of Dry Wells

= 430 ft² / 4 = **107.5-ft²**

Each dry well will be 10' x 11' to meet the minimum surface area requirements.

Volume:

Find the infiltration volume for each dry well based on the expected runoff volume.

Land Use	Soil Type	Area	Area	CN	S	I _a	Runoff Depth _{2-yr}	Runoff Volume _{2-yr}
	(HSG)	(sf)	(acres)			(0.2*S)	(in)	(ft ³)
Open Space (good)	B	110	0.00	61	6.393	1.279	0.28	3
Impervious	B	540	0.01	98	0.204	0.041	2.53	114
TOTAL:		650	0.01				2.81	116

Runoff volume = **116-ft³**

Appendix B – Supporting Calculations for the Design Example

Depth:

Each dry well will be filled with aggregate. The in-place aggregate will have a 40% voids ratio; therefore the volume is divided by the available void space to get a total volume.

Depth = Total Volume / Surface Area

$$= (116\text{-ft}^3 / 0.40) / 110\text{-ft}^2 = \mathbf{2.64\text{-ft or approximately 2'-8"}}$$

An overflow spillway or drain is then sized to convey any runoff that exceeds the design volume to the peak rate management facility.

Rain Gardens

(Example calculations shown for Lot #1; Refer to Worksheet 5A for additional calculations)

Surface Area:

Find the minimum surface area for each rain garden based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)

Tributary impervious area = 1,000-ft²

$$= 1,000\text{-ft}^2 / 5 = \mathbf{200\text{-ft}^2}$$

= minimum surface area of rain garden per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1

Total drainage area = 6,000-ft² (typ.)

$$= 6,000\text{-ft}^2 / 8 = \mathbf{750\text{-ft}^2}$$

= minimum surface area of rain garden per pervious loading ratio

The larger of the two calculated areas is the minimum surface area required for the facility.

$$\text{Minimum Rain Garden Surface Area} = \mathbf{750\text{-ft}^2}$$

Depth:

Design guidelines, from the *PA BMP Manual*, for rain gardens limit ponding depth within the facility to 12 inches or less. The rain gardens in this example have been designed with a total ponding depth of 12 inches. The overflow outlets are positioned 6 inches above the bottom elevation of the rain gardens and 6 inches of freeboard is provided above the overflow outlets.

Volume:

The total detention volume of the rain garden is calculated by multiplying the surface area of the rain garden by the total depth. The 6 inches of water below the overflow outlet will be infiltrated and the remaining depth is used as short-term retention while flow is regulated through the overflow device. When calculating the infiltration volume, the bottom surface area of the BMP must be used.

Infiltration Volume = Surface Area x Depth

$$= 700\text{-ft}^2 \times 0.5\text{-ft} = \mathbf{350\text{-ft}^3}$$

Bioretention

(Refer to Worksheet 5A for additional calculations)

Surface Area:

Find the minimum surface area for the bioretention facility based on the maximum loading ratios.

Appendix B – Supporting Calculations for the Design Example

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)
Tributary impervious area = 9,700-ft² (typ.)
= 9,700-ft² / 5 = **1,940-ft²**
= minimum surface area of Infiltration Trench per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1
Total drainage area = 41,400-ft²
= 41,400-ft² / 8 = **5,175-ft²**
= minimum surface area of Infiltration Trench per pervious loading ratio

The larger of the two calculated areas is the minimum surface area required for the facility.

Minimum Infiltration Trench Surface Area = **5,175-ft²**

Depth:

The bioretention facility in this example has been designed with a total depth of 18 inches. The overflow outlets are positioned 6 inches above the bottom elevation, and 12 inches of freeboard is provided above the overflow outlets.

Volume:

The total detention volume of the bioretention facility is calculated by multiplying the surface area by the total depth. The 6 inches of water below the overflow outlet will be infiltrated and the remaining depth is used as short-term retention while flow is regulated through the overflow device. When calculating the infiltration volume, the bottom surface area of the BMP must be used.

Infiltration Volume = Surface Area x Depth
= 5,175-ft² x 0.5-ft = **2,487.5-ft³**

STRUCTURAL CONTROL VOLUME REQUIREMENT CHECK

(Refer to *Worksheet 5*)

Check the total structural volume to be certain it is adequate to meet the structural volume requirement.

= Total Structural Volume - Structural Volume Requirement
= 14,613-ft³ - 11,984-ft³ = 2,629-ft³

The structural volume requirement has been exceeded by 2,629-ft³ and no further BMP calculations are necessary.

Appendix B – Supporting Calculations for the Design Example



Project Name: DESIGN EXAMPLE 1
 Project ID: MILL RUN RESIDENTIAL
 Owner: _____
 Calculated: _____ Date: _____
 Checked: _____ Date: _____

WORKSHEET 1. GENERAL SITE INFORMATION		
INSTRUCTIONS: Fill out <i>Worksheet 1</i> for each watershed		
Date:	_____	
Project Name:	<u>DESIGN EXAMPLE 1</u>	
Municipality:	_____	
County:	_____	
Total Area (acres):	<u>9.78</u>	
Major River Basin:	_____	
	http://www.dep.state.pa.us/dep/deputate/watermgt/wc/default.htm#newtopics	
Watershed:	_____	
Sub-Basin:	<u>N/A</u>	
Nearest Surface Water(s) to Receive Runoff:	_____	
Chapter 93 - Designated Water Use:	<u>CWF</u>	
	http://www.pacode.com/secure/data/025/chapter93/chap93toc.html	
Impaired according to Chapter 303(d) List?	Yes	☐
	No	☒
http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/303d-Report.htm		
List Causes of Impairment: _____		
<i>Is project subject to, or part of:</i>		
Municipal Separate Storm Sewer System (MS4) Requirements?	Yes	☐
	No	☒
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralPermits/default.htm		
Existing or planned drinking water supply?	Yes	☐
	No	☒
If yes, distance from proposed discharge (miles):	_____	
Approved Act 167 Plan?	Yes	☒
	No	☐
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/Approved_1.html		
Existing River Conservation Plan?	Yes	☐
	No	☒
http://www.dcnr.state.pa.us/brc/rivers/riversconservation/planningprojects/		

Appendix B – Supporting Calculations for the Design Example



Project Name: DESIGN EXAMPLE 1
 Project ID: MILL RUN RESIDENTIAL
 Owner: _____
 Calculated: _____ Date: _____
 Checked: _____ Date: _____

WORKSHEET 2. SENSITIVE NATURAL RESOURCES

INSTRUCTIONS:

1. Provide Sensitive Resources Map according to non-structural BMP 5.4.1 in Chapter 5 of PA Stormwater BMP Manual. This map should identify waterbodies, floodplains, riparian areas, wetlands, woodlands, natural drainage ways, steep slopes, and other sensitive natural areas.

2. Summarize the existing extent of each sensitive resource in the Existing Sensitive Resources Table (below, using Acres). If none present, insert 0.

3. Summarize Total Protected Area as defined under BMPs in Chapter 5.

4. Do not count any area twice. For example, an area that is both a floodplain and a wetland may only be considered once.

EXISTING NATURAL SENSITIVE RESOURCE	MAPPED? yes/no/n/a	TOTAL AREA (Ac.)	PROTECTED AREA (Ac.)
Waterbodies	yes	0.00	
Floodplains	no	0.00	
Riparian Areas	no	0.00	
Wetlands	no	0.00	
Woodlands	yes	2.29	1.31
Natural Drainage Ways	N/A	0.00	
Steep Slopes, 15% - 25%	N/A	0.00	
Steep Slopes, over 25%	N/A	0.00	
Other:	N/A		
Other:	N/A		
TOTAL EXISTING:		2.29	1.31

Appendix B – Supporting Calculations for the Design Example



Project Name: DESIGN EXAMPLE 1
 Project ID: MILL RUN RESIDENTIAL
 Owner: _____
 Calculated: _____ Date: _____
 Checked: _____ Date: _____

WORKSHEET 3. NON-STRUCTURAL BMP CREDITS																			
PROTECTED AREA																			
1.1 Area of Protected Sensitive/Special Value Features (see WS 2)								1.31 Ac.											
1.2 Area of Riparian Forest Buffer Protection								0.00 Ac.											
3.1 Area of Minimum Disturbance/Reduced Grading								0.37 Ac.											
TOTAL								1.68 Ac.											
<table style="margin: auto; border: 1px solid black;"> <tr> <td style="text-align: center;">Site Area</td> <td style="text-align: center;">minus</td> <td style="text-align: center;">Protected Area</td> <td style="text-align: center;">=</td> <td style="text-align: center;">Stormwater Management Area</td> </tr> <tr> <td style="text-align: center; border: 1px solid black;">9.78</td> <td style="text-align: center;">-</td> <td style="text-align: center; border: 1px solid black;">1.68</td> <td style="text-align: center;">=</td> <td style="text-align: center; border: 1px solid black;">8.10</td> </tr> </table>										Site Area	minus	Protected Area	=	Stormwater Management Area	9.78	-	1.68	=	8.10
Site Area	minus	Protected Area	=	Stormwater Management Area															
9.78	-	1.68	=	8.10															
VOLUME CREDITS																			
3.1 Minimum Soil Compaction																			
Lawn	16,165	ft ²	x 1/4"	x 1/12	=	337 ft ³													
Meadow	N/A	ft ²	x 1/3"	x 1/12	=	0 ft ³													
3.3 Protect Existing Trees																			
<i>For Trees within 100 feet of impervious area:</i>																			
Tree Canopy	N/A	ft ²	x 1/2"	x 1/12	=	0 ft ³													
<i>For Trees within 20 feet of impervious area:</i>																			
Tree Canopy	N/A	ft ²	x 1"	x 1/12	=	0 ft ³													
5.1 Disconnect Roof Leaders to Vegetated Areas																			
<i>For runoff directed to areas protected under 5.8.1 and 5.8.2</i>																			
Roof Area	N/A	ft ²	x 1/3"	x 1/12	=	0 ft ³													
<i>For all other disconnected roof areas</i>																			
Roof Area	N/A	ft ²	x 1/4"	x 1/12	=	0 ft ³													
5.2 Disconnect Non-Roof Impervious to Vegetated Areas																			
<i>For Runoff directed to areas protected under 5.8.1 and 5.8.2</i>																			
Impervious Area	10,000	ft ²	x 1/3"	x 1/12	=	278 ft ³													
<i>For all other disconnected non-roof impervious areas</i>																			
Impervious Area	N/A	ft ²	x 1/4"	x 1/12	=	0 ft ³													
TOTAL NON-STRUCTURAL VOLUME CREDIT*								615 ft³											
* For use on Worksheet 5																			

Appendix B – Supporting Calculations for the Design Example



Project Name: DESIGN EXAMPLE 1

Project ID: MILL RUN RESIDENTIAL

Owner:

Calculated: _____ Date: _____

Checked: _____ Date: _____

WORKSHEET 4. CHANGE IN RUNOFF VOLUME FOR 2-YR STORM EVENT

PROJECT: DESIGN EXAMPLE 1

Drainage Area: 8.10 (acres)

2-Year Rainfall: 2.76 inches (From NOAA Atlas 14)

Total Site Area: 9.78 acres

Protected Site Area: 1.68 acres

Stormwater Management Area: 8.10 acres (From Worksheet 3)

Existing Conditions:

Land Use	Soil Type (HSG)	Area (sf)	Area (acres)	CN	S	Ia (0.2*S)	Q Runoff ¹ (in)	Runoff Volume ² (ft ³)
Woods (good)	B	42,500	0.98	55	8.1818	1.6364	0.14	481
Meadow	B	310,255	7.12	58	7.2414	1.4483	0.20	5,201
								-
								-
								-
TOTAL:		352,755	8.10					5,682

Developed Conditions:

Land Use	Soil Type (HSG)	Area (sf)	Area (acres)	CN	S	Ia (0.2*S)	Q Runoff ¹ (in)	Runoff Volume ² (ft ³)
Meadow	B	54,060	1.24	58	7.2414	1.4483	0.20	906
Open Space (good)	B	243,035	5.58	61	6.3934	1.2787	0.28	5,643
Impervious	B	55,660	1.28	98	0.2041	0.0408	2.53	11,732
								-
								-
TOTAL:		352,755	8.10					18,281

2-Year Volume Increase (ft³): 12,599

$$\begin{aligned} \text{2-Year Volume Increase} &= \text{Developed Conditions Runoff Volume} - \text{Existing Conditions Runoff Volume} \\ &= 18,281 - 5,682 = 12,599 \text{ ft}^3 \end{aligned}$$

- Runoff (in) = $Q = (P - 0.2S)^2 / (P + 0.8S)$ where
P = 2-Year Rainfall (in)
S = $(1000 / CN) - 10$

- Runoff Volume (CF) = $Q \times \text{Area} \times 1/12$
Q = Runoff (in)
Area = Land use area (sq. ft)

Note: Runoff Volume must be calculated for EACH land use type/condition and HSG.
The use of a weighted CN value for volume calculations is not acceptable.

Appendix B – Supporting Calculations for the Design Example



Project Name: DESIGN EXAMPLE 1
 Project ID: MILL RUN RESIDENTIAL
 Owner: _____
 Calculated: _____ Date: _____
 Checked: _____ Date: _____

WORKSHEET 5. STRUCTURAL BMP VOLUME CREDITS

SUB-BASIN: N/A

Check 25% Limit for Non-Structural BMP Credits: 815
 $\div$ 12,599
4.9%

Required Control Volume (ft³): 12,599
 Allowable Non-structural Volume Credit (ft³): - 815

Structural Volume Reqmt (ft³): 11,984
 (Required Control Volume minus Non-structural Credit)

Proposed BMP		Area (ft ²)	Infiltration Volume (ft ³)
6.4.1	Porous Pavement		
6.4.2	Infiltration Basin		
6.4.3	Infiltration Bed		
6.4.4	Infiltration Trench		
6.4.5	Rain Garden/Bioretenion	11,915	8,827
6.4.6	Dry Well / Seepage Pit	4,400	5,787
6.4.7	Constructed Filter		
6.4.8	Vegetated Swale		
6.4.9	Vegetated Filter Strip		
6.4.10	Berm		
6.5.1	Vegetated Roof		
6.5.2	Capture and Re-use		
6.6.1	Constructed Wetlands		
6.6.2	Wet Pond / Retention Basin		
6.6.3	Dry Extended Detention Basin		
6.6.4	Water Quality Filters		
6.7.1	Riparian Buffer Restoration		
6.7.2	Landscape Restoration / Reforestation		
6.7.3	Soil Amendment		
6.8.1	Level Spreader		
6.8.2	Special Storage Areas		
Other			

Total Structural Volume (ft³): 14,613
 Structural Volume Requirement (ft³): 11,984

DIFFERENCE: 2,629 (excess)

* Complete BMP Design Checklist for each measure proposed
 NOTE: Provide supporting Volume Calculations for each Structural BMP

Appendix B – Supporting Calculations for the Design Example



Project Name: DESIGN EXAMPLE 1
 Project ID: MILL RUN RESIDENTIAL
 Designer:
 Calculated:
 Checked:
 Date:
 Date:

WORKSHEET 6.A - INFILTRATION BMP SUPPORTING CALCULATIONS

Instructions: Complete this worksheet for each Point of Interest / Discharge (at a minimum)

Point of Interest / Discharge:
 Total Drainage Area to POI:
 Total Impervious Area:

Proposed Infiltration BMP(s)	Infiltration Rate		Design		Infiltration Period		Imperv. Drainage Area Loading		Total Drainage Area Loading		Actual BMP Area ⁴ sq. ft.	Computed Infiltration Volume cu. ft.
	Measured Infiltration ¹ in/hr	FOS	Infiltration Rate in/hr	Design Runoff Volume cu. ft.	Infiltration Period hrs	Active Infiltration Period hrs	Total Infiltration Period hrs	Imperv. Area Loading sq. ft.	% area draining to BMP ²	Total Drainage Area Loading sq. ft.	Total Target Area Loading sq. ft.	
BMP 6.4.1 Pervious Pavement w/ Infiltr. Bed												
BMP 6.4.2 Infiltration Basin												
BMP 6.4.3 Subsurface Infiltration Bed												
BMP 6.4.4 Infiltration Trench												
BMP 6.4.5 Rain Garden/Stormwater												
Rain Garden (Lot #1)	0.93	2	0.47	360	12.6	6	18.6	1,000	100.0	4,776	5,97	513
Rain Garden (Lot #2)	0.95	2	0.48	360	12.6	6	18.6	1,000	100.0	5,000	700	516
Rain Garden (Lot #3)	0.98	2	0.49	360	12.6	6	18.6	1,000	100.0	5,000	636	522
Rain Garden (Lot #4)	1.01	2	0.51	360	11.9	6	17.9	1,000	100.0	3,625	453	452
Rain Garden (Lot #5)	1.02	2	0.51	458	11.8	6	17.8	1,000	100.0	7,005	876	691
Rain Garden (Lot #6)	1.08	2	0.54	360	11.1	6	17.1	1,000	100.0	5,310	664	519
Rain Garden (Lot #7)	0.91	2	0.46	300	13.2	6	19.2	1,000	100.0	4,365	549	437
Rain Garden (Lot #8)	0.99	2	0.50	258	12.1	6	18.1	1,000	100.0	3,000	375	365
Rain Garden (Lot #9)	1.05	2	0.53	300	11.4	6	17.4	1,000	100.0	4,500	565	458
Rain Garden (Lot #10)	1.03	2	0.52	375	11.7	6	17.7	1,000	100.0	4,975	622	568
Stormwater 1	0.92	2	0.46	258	13.0	6	19.0	9,700	100.0	1,940	5,175	3,778
BMP 6.4.6 Dry Well/ Sewerage Pit												
Dry Well (Lot #1)	0.98	2	0.48	458	25.0	6	32.0	2,150	100.0	430	430	440
Dry Well (Lot #2)	0.91	2	0.46	458	25.1	6	34.1	2,150	100.0	430	430	440
Dry Well (Lot #3)	1.06	2	0.53	458	24.1	6	30.1	2,150	100.0	430	430	440
Dry Well (Lot #4)	1.02	2	0.51	458	25.0	6	31.0	2,150	100.0	430	430	440
Dry Well (Lot #5)	0.93	2	0.47	458	27.4	6	33.4	2,150	100.0	430	430	440
Dry Well (Lot #6)	1.07	2	0.54	458	23.9	6	29.9	2,150	100.0	430	430	440
Dry Well (Lot #7)	0.97	2	0.46	458	26.3	6	32.3	2,150	100.0	430	430	440
Dry Well (Lot #8)	1.01	2	0.51	458	25.3	6	31.3	2,150	100.0	430	430	440
Dry Well (Lot #9)	1.04	2	0.52	458	24.5	6	30.5	2,150	100.0	430	430	440
Dry Well (Lot #10)	1.07	2	0.54	458	23.9	6	29.9	2,150	100.0	430	430	440
BMP 6.4.7 Constructed Filter												
BMP 6.4.8 Vegetated Swale ³												
BMP 6.4.9 Vegetated Filter Strip ³												
BMP 6.4.10 Infiltr. Berm & Ret. Grading												
TOTAL												14,613

1 Assumes a soil testing procedure which finds hydraulic conductivity. (e.g. percolation may decrease as reduction factor)

2 Time it takes for BMP to empty once it is full. (Minimum = 24 hrs, Maximum = 72 hours. Applicable to retention and detention facilities only.)

3 Infiltration that occurs during the storm (before becoming full). Not to exceed 6 hours.

4 A portion of the total area is draining to BMP from non-pervious area may be allowed.

5 Inherent in these calculations are the allowable loading rates (0.1 and 0.1) from the BMP Manual. Higher loading rates will need to be justified. Inherent Areas, however, loading rates should be 0.1.

Appendix B – Supporting Calculations for the Design Example

PEAK RATE CONTROL ANALYSIS

According to the National Engineering Handbook (NRCS, 2008), the direct runoff for watersheds having more than one hydrologic soil-cover complex can be estimated in either of two ways. Runoff can be estimated for each complex and then weighted to get the watershed average. Alternatively, the CN values can be weighted, based on area, to obtain a single CN value to represent the entire drainage area. Then runoff is estimated with the single CN value. If the CN for the various hydrologic soil-cover complexes are close in value, both methods of weighting give similar results for runoff. However, if there exists a large difference in curve number value, the CN weighting method can provide drastically different results.

As described in the *National Engineering Handbook*, “the method of weighted runoff always gives the correct result (in terms of the given data), but it requires more work than the weighted CN method, especially when a watershed has many complexes. The method of weighted CN is easier to use with many complexes or with a series of storms. However, where differences in CN for a watershed are large, this method either under- or over-estimates runoff, depending on the size of the storm.” This often occurs when impervious area exists in a subarea. When the relatively low curve number of lawn areas is combined with the high curve number of impervious areas, the weighted CN method will minimize the impact of the impervious surface and underestimate the amount of runoff.

The spatial distribution of the different soil-cover complexes becomes the controlling factor in selection of the appropriate method. When different land uses behave as independent watershed the areas should be analyzed as separate drainage subareas. For example, when a large parking area is surrounded by lawn area that all flows to the same collection point, runoff from the impervious surface will occur much differently than runoff from the lawn. However, when impervious area is dispersed amongst other land uses and not directly connected to a stormwater collection system, the weighted CN method may be appropriate. The decision of whether or not to use a weighted curve number is often a site specific judgment that should be discussed between the designer and the Municipal Engineer in the early planning stages of a project.

Pre-Development Soil-Cover Complex Data

Because the wooded area along the north property line will remain unchanged, and will not be tributary to the stormwater facilities, this area has been removed from the peak rate analysis drainage areas. The weighted CN method was used for pre-development calculations in this example because Curve Numbers for the hydrologic soil-cover complexes are close in value. The drainage area and land cover information necessary to calculate the pre-development runoff is shown in the table below:

Land Use	Soil Type (HSG)	Area (ft ²)	Area (acres)	CN
Woods (good)	B	42,500	0.98	55
Meadow	B	310,255	7.12	58
TOTAL:		352,755	8.10	58

Pre-Development Time of Concentration

The *Model Ordinance* requires use of the NRCS Lag Equation for all pre-development time of concentration calculations unless another method is pre-approved by the Municipal Engineer.

Appendix B – Supporting Calculations for the Design Example

$$T_{lag} = L^{0.8} \frac{(S + 1)^{0.7}}{1900\sqrt{Y}}$$

Where:

T_{lag} = Lag time (hours)

L = Hydraulic length of the watershed (feet)

Y = Average overland slope of watershed (percent)

S = Maximum retention in the watershed, as defined by: $S = [(1000/CN) - 10]$

CN = NRCS Curve Number for the watershed

Lag time is related to time of concentration by the following equation:

$$\text{Time of Concentration} = T_c = [(T_{lag}/.6) * 60] \text{ (minutes)}$$

One method of calculating the average overland slope of a watershed is to select locations that represent the various slopes found in the watershed and weight the slope based on the area it represents. This method is shown in the table on the following page.

Slope	End Elevation		Distance	Slope	Percent of	Product
Line	High	Low	(ft)	(%)	Total Area	(% x %)
AA	909	902	148	4.7%	5%	0.24%
BB	941	909	475	6.7%	50%	3.37%
CC	956	942	245	5.7%	15%	0.86%
DD	960	943	180	9.4%	15%	1.42%
EE	943	930	265	4.9%	15%	0.74%
					Sum of Products =	6.61%

This is an estimation of the land slope value, so the calculated number is rounded to the nearest whole number for use in the Lag Equation. The hydraulic length of the watershed was measured at 1050 ft. Therefore,

$$T_{lag} = (1050)^{0.8} \frac{((1000 / CN) - 10) + 1)^{0.7}}{1900\sqrt{7}}$$

$$T_{lag} = 0.23 \text{ hours}$$

$$\begin{aligned} \text{Time of Concentration} = T_c &= (T_{lag} / 0.6) * 60 \\ &= (0.23 / 0.6) * 60 \\ &= 23 \text{ minutes} \end{aligned}$$

Pre-Development Peak Rate Flows

All of this information was used to perform a pre-development peak rate analysis using a software package based on the NRCS TR-20 procedures. The results of the analysis are as follows:

	1-year	2-year	10-year	25-year	50-year	100-year
Peak Runoff Flows (cfs)	0.1	0.6	4.1	7.6	11.1	15.3
Runoff Volume (ac-ft)	0.060	0.136	0.449	0.726	0.997	1.322
Runoff Depth (in)	0.09	0.20	0.66	1.08	1.48	1.96

Table B.1. Pre-Development Runoff Summary

Appendix B – Supporting Calculations for the Design Example

Post-Development Soil-Cover Complex Data

Due to the disconnection of impervious areas and overland flow paths used in this design, the area weighted CN method was deemed appropriate and used to reduce the complexity of the model. The drainage area and land cover information for the drainage sub-area directly tributary to the bioretention facility is shown in the table below:

Land Use	Soil Type (HSG)	Area (ft ²)	Area (acres)	CN
Lawn (good condition)	B	9,700	0.22	61
Impervious	B	31,700	0.73	98
TOTAL:		41,400	0.95	70

Post-Development Time of Concentration

The Segmental Method was used for all post-development time of concentration calculations in this example. This method is covered in more detail in various NRCS publications (NRCS, 1986; NRCS, 2008). The following segments were used to calculate a time of concentration for the drainage sub-area directly tributary to the bioretention facility:

- T_{t-1} : Sheet flow, 100' of lawn at 5% = 10.7 min
- T_{t-2} : Shallow concentrated flow, 110' unpaved at 5.9% = 0.5 min
- T_{t-3} : Channel flow, 80' at 4.0% = 0.2 min
- T_{t-4} : Channel flow, 156' at 3.85% = 0.5 min
- T_{t-5} : Pipe flow, 38' of 15" HDPE pipe at 5.2% = 0.1 min

$$T_c = T_{t-1} + T_{t-2} + T_{t-3} + T_{t-4} + T_{t-5} = 12 \text{ minutes}$$

Post-Development Peak Rate Flows

The hydrologic model for this example contains a considerable level of detail. Each structural BMP was modeled as a pond with a unique drainage area and time of concentration. Runoff was routed through each BMP and linked to downstream BMPs for subsequent routing. A detention basin with an outlet control structure was also added to the model. A graphical representation of the model is provided in *Figure B.1*.

Appendix B – Supporting Calculations for the Design Example

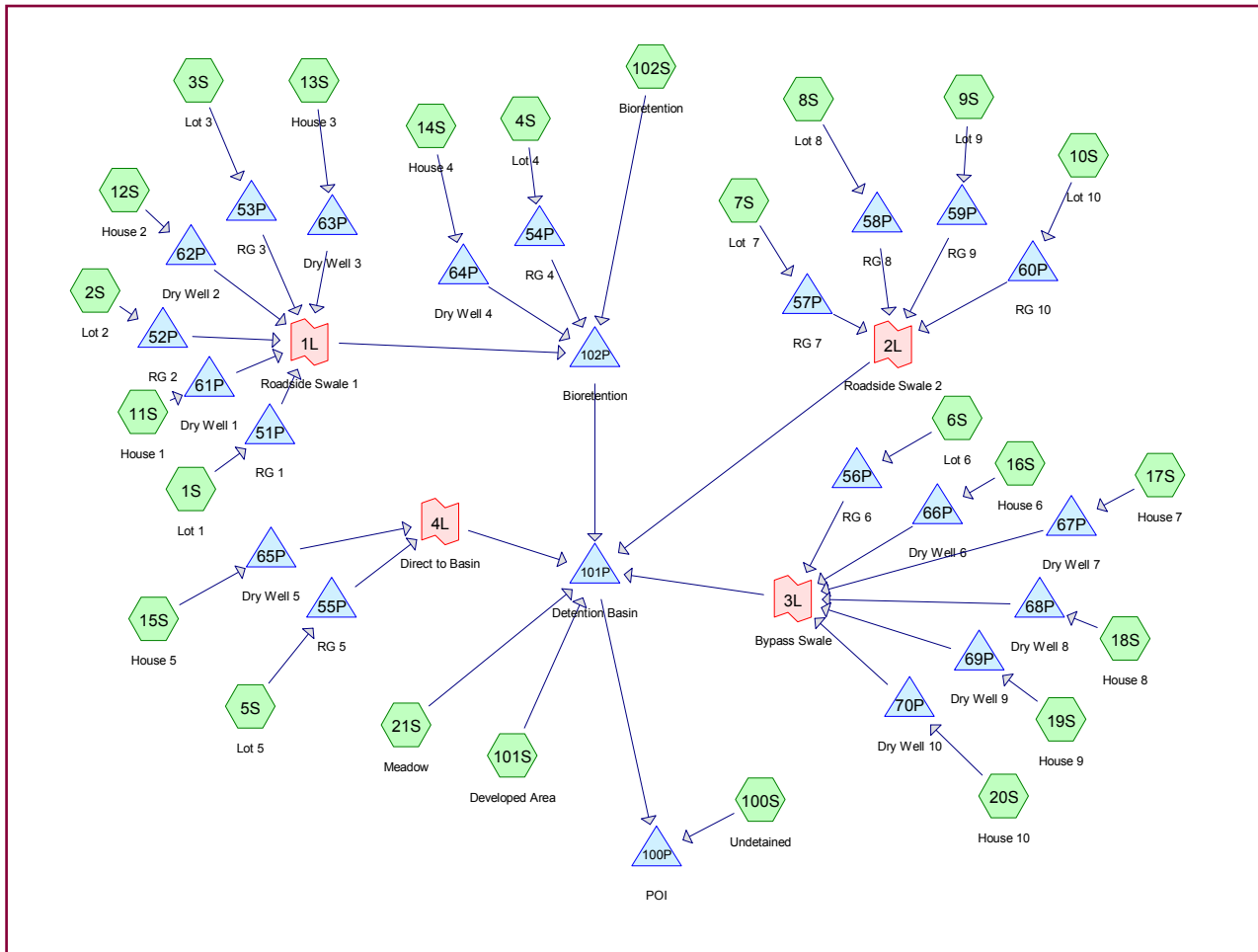


Figure B.1. Hydrologic Model of Post-Development Conditions

This model was used to estimate the post-development peak rate flows. The final configuration of the outlet structure was completed through an iterative process using the results of the model runs. This design meets the peak rate control requirements through a combination of volume removed by the structural BMPs and the detention basin and outlet control structure. Table B.2 shows a summary of the runoff results for the final post-development design:

	1-year	2-year	10-year	25-year	50-year	100-year
Peak Runoff Flows (cfs)	0.1	0.4	4.1	7.4	10.6	15.2
Runoff Volume (ac-ft)	0.079	0.147	0.445	0.717	1.011	1.367
Runoff Depth (in)	0.12	0.22	0.66	1.06	1.50	2.03

Table B.2. Summary of Post-Development Runoff with Stormwater Controls

Appendix B – Supporting Calculations for the Design Example

INITIAL CONSTRUCTION COST - DESIGN EXAMPLE

Initial construction costs were estimated for each layout. The estimates include the costs incurred by the developer to complete earthwork, paving and curbing, and stormwater management facilities. All of these costs are summed to determine an initial construction cost for these facilities. This cost was then divided by the total sellable acreage of the project to determine a cost / sellable acre for each layout.

Estimate of Initial Construction Cost Mill Run Residential – Traditional Layout					
ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
EARTHWORK				Subtotal =	\$ 23,950
1	Clearing & Grubbing	2.3	AC	\$ 6,000.00	\$ 13,800
2	Topsoil Removal/Stockpiling	5.8	AC	\$ 1,750.00	\$ 10,150
STORM DRAINAGE				Subtotal =	\$ 102,769
3	Storm Sewer, 18" HDPE	600	LF	\$ 55.00	\$ 33,000
4	Storm Inlets	7	EA	\$ 2,100.00	\$ 14,700
5	Swales	490	LF	\$ 10.00	\$ 4,900
6	Install Detention Basin	1,525	CY	\$ 25.00	\$ 38,125
7	Anti Seep Collars	2	EA	\$ 775.00	\$ 1,550
8	Outlet Structure	1	EA	\$ 4,000.00	\$ 4,000
9	Outlet Pipe, 18" HDPE	50	LF	\$ 55.00	\$ 2,750
10	DW Endwall 24"	1	EA	\$ 2,750.00	\$ 2,750
11	Rip Rap Apron	144	SF	\$ 6.90	\$ 994
PAVING & CURBING				Subtotal =	\$ 138,657
12	Paving - Final Subgrade, 6" Stone, 3" 19MM, 1-1/2" 9.5mm	2,325	SY	\$ 30.00	\$ 69,750
13	Curbing w/Excavation & Backfill	1,465	LF	\$ 27.00	\$ 39,555
14	Sidewalk plain w/4" - stone	4,285	SF	\$ 6.85	\$ 29,352
Initial Construction Cost =				\$ 265,376	
Cost / Sellable Acre =				\$ 42,734	

Table B.3. Estimate of Construction Cost for Residential Design Example (Traditional Layout)

Appendix B – Supporting Calculations for the Design Example

Estimate of Initial Construction Cost Mill Run Residential – LID Layout					
ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
EARTHWORK				Subtotal =	\$ 14,925
1	Clearing & Grubbing	1.0	AC	\$ 6,000.00	\$ 6,000
2	Topsoil Removal/Stockpiling	5.1	AC	\$ 1,750.00	\$ 8,925
STORM DRAINAGE				Subtotal =	\$ 114,172
3	Swales	1,620	LF	\$ 10.00	\$ 16,200
4	Storm Sewer, 18" HDPE	136	LF	\$ 55.00	\$ 7,480
5	DW Headwall 18"	1	EA	\$ 2,750.00	\$ 2,750
6	Storm Inlets	1	EA	\$ 2,100.00	\$ 2,100
7	Install Detention Basin	600	CY	\$ 25.00	\$ 15,000
8	Anti Seep Collars	2	EA	\$ 775.00	\$ 1,550
9	Outlet Structure	1	EA	\$ 4,000.00	\$ 4,000
10	Outlet Pipe, 18" HDPE	50	LF	\$ 55.00	\$ 2,750
11	Level Spreader	44	LF	\$ 5.50	\$ 242
12	Bioretention Area	5,175	SF	\$ 12.00	\$ 62,100
PAVING & CURBING				Subtotal =	\$ 53,790
13	Paving - Final Subgrade, 6" Stone, 3" 19MM, 1-1/2" 9.5mm	1,645	SY	\$ 30.00	\$ 49,350
14	Gravel Shoulder	370	SY	\$ 12.00	\$ 4,440
				Initial Construction Cost =	\$ 182,887
				Cost / Sellable Acre =	\$ 28,355

Table B.4. Estimate of Construction Cost for Residential Design Example (LID Layout)

The cost of constructing the stormwater BMPs on each individual lot was not included in the comparison of initial construction costs. This is a cost that will be borne by the owner of each individual lot. This must be included in the cost comparison analysis. *Table B.5* shows an estimate of these costs.

Estimate of Stormwater BMP Construction Cost Mill Run Residential – LID Layout					
ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
STORMWATER BMPs					
1	Rain Gardens	6,740	SF	\$ 10.00	\$ 67,400
2	Dry Wells	450	CY	\$ 32.00	\$ 14,400
				Construction Cost =	\$ 81,800
				Cost / Sellable Acre =	\$ 12,682

Table B.5. Estimate of Stormwater BMP Construction Cost

Determining how this additional cost to homeowners will be reflected in the market value of developed land is presumptive at best. For this example, we have assumed that some of the cost of constructing the stormwater BMPs will result in a dollar for dollar reduction in the market value of the sellable land. So, the BMP construction cost per sellable acre is subtracted from the per acre market value price of the land.

Appendix B – Supporting Calculations for the Design Example

The initial construction cost is subtracted from the land sale value to determine the developers profit for each layout.

$$\text{Cost} = \text{Land Sale Value} - \text{Initial Construction Cost}$$

Traditional Layout

$$\begin{aligned}\text{Cost} &= \$310,500 - \$265,376 \\ &= \$45,124\end{aligned}$$

LID Layout

$$\begin{aligned}\text{Cost} &= \$240,701 - \$182,887 \\ &= \$57,814\end{aligned}$$

The final cost comparison is completed by determining the difference in profit between the two layouts. For this example, a total profit increase of \$12,690 is realized by the developer using the LID layout with no additional cost to the individual homeowners.

Venango County Act 167 Plan

Municipality: Barkeyville

ID: P1

Problem Description: Along SR 8, south of SR 208 intersection. Blocked culvert downstream of intersection. PENNDOT has cleaned the ditch in the past. 12" RCP is almost completely blocked with sediment. About 1 1/2" of top of pipe is exposed.

Photos:



Photo Description:

Obstructed 12" concrete pipe is beneath the large stone.



Photo Description:

Close-up of obstructed pipe.

Conceptual Solution:

PENNDOT is responsible for performing regular maintenance consisting of ditch cleaning and pipe cleaning, since the pipe was installed in the state right-of-way.

Venango County Act 167 Plan

Municipality: Barkeyville

ID: P2

Problem Description: Cockain Road Culvert causes streambank erosion. 24" CPP causes erosion and deposition in the farmer's field.

Photos:



Photo Description:

Downstream view of 24" CPP discharging into a pasture field. Severe erosion and deposition are apparent immediately downstream of crossing.



Photo Description:

Upstream view of channel and roadside swales draining to 24" CPP. Some erosion is evident.

Conceptual Solution:

The Borough is permitted to maintain the channel upstream and downstream of a road crossing for a distance of 50' without the need for a permit from DEP. Streambank rehabilitation may be warranted. Also, the property owner should consider planting vegetation in the riparian zone of the stream.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O13

Problem Description: Tarr Woods Culvert (T-595) - Erosion

Photos:



Photo Description:

Downstream end of concrete arch culvert.



Photo Description:

Upstream end of concrete arch culvert.

Conceptual Solution:

No erosion was evident due to heavy snow cover.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O12A

Problem Description: SR 8 over unnamed tributary to Cherrytree Run in the Village of Cherrytree.

Photos:



Photo Description:

Upstream face of steel beam bridge.



Photo Description:

Looking downstream beneath the steel beam bridge.

Conceptual Solution:

Stream channel seems healthy, and there is only minor erosion around the bridge abutments. The stated problem area may refer to another bridge in the village of Cherrytree.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O12

Problem Description: Erosion was noted upstream along the steep bank and downstream in the yard of an adjacent property owner. Debris and trees partially block the flow at the upstream face of the structure.

Photos:



Photo Description:

Erosion of the steep bank upstream of the concrete beam bridge.



Photo Description:

Upstream face of concrete beam bridge with debris and trees obstructing flow.

Conceptual Solution:

Channel cleaning should be performed to remove debris and trees. Streambank rehabilitation upstream and downstream where streambanks are steep.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O11

Problem Description: There are signs of erosion around the cut stone wingwalls and the streambanks. A pool appears to have formed in the stream channel at the downstream end of the structure.

Photos:



Photo Description:

Lamey Road (T518) over unnamed tributary, looking upstream.



Photo Description:

Closer view of the aluminum pipe arch, looking upstream.

Conceptual Solution:

The Borough is permitted to maintain the channel upstream and downstream of a road crossing for a distance of 50' without the need for a permit from DEP. The deteriorating wingwalls could be removed and replaced. Streambank mitigation may also be warranted to stabilize the streambanks. The stream channel downstream of the culvert could be armored with riprap to prevent erosion and scour.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O3

Problem Description: The Borough identified erosion as a problem, but no erosion was visible due to the snow cover.

Photos:



Photo Description:

View of the downstream face of the concrete box culvert that carries T540 (Cherrytree Road) over an unnamed tributary.



Photo Description:

Another view of the downstream face of the concrete box culvert.

Conceptual Solution:

Wherever streambank erosion is a problem, the streambanks should be rehabilitated by excavating the banks to a mild slope and armoring with riprap and woody plantings.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O16

**Problem
Description:**

Moderate streambank erosion exists downstream of the structure.

Photos:



Photo Description:

Downstream end of 36" Plastic Pipe which conveys stormwater beneath T669 (Black Road).



Photo Description:

View of Downstream channel showing moderate erosion on the right bank.

**Conceptual
Solution:**

Wherever streambank erosion is a problem, the streambanks should be rehabilitated by excavating the banks to a mild slope and armoring with riprap and woody plantings.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O4

Problem Description: Erosion of the steep streambanks is present downstream of the 48" plastic pipe.

Photos:



Photo Description:

View of the downstream end of the 48" plastic pipe that conveys a stream beneath T574 (Shreve Road).



Photo Description:

Looking downstream of the culvert crossing. The worst erosion is visible on the left bank.

Conceptual Solution:

Streambank stabilization to the left bank downstream of the culvert. The Borough is permitted to maintain the channel upstream and downstream of a road crossing for a distance of 50' without the need for a permit from DEP

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O8

Problem Description: Erosion to the streambanks and channel.

Photos:



Photo Description:

View of the upstream face of the steel pipe arch culvert that carries Fairview Road (T649) across the stream.



Photo Description:

Erosion in the upstream channel.

Conceptual Solution:

Streambank stabilization along both banks upstream of the structure.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O10

Problem Description: Streambank erosion upstream of the crossing.

Photos:



Photo Description:

Upstream face of the corrugated metal pipe culvert that carries Cherrytree Road (T540) across the stream.



Photo Description:

View upstream of the culvert showing a pool that has been excavated. A dry hydrant has been installed along Cherrytree Road, which may be used by the local fire department to fill their tankers. There is also evidence that the adjacent landowner allows cattle to graze in and along the channel in this area.

Conceptual Solution:

Perform streambank rehabilitation upstream of the structure. Also, the riparian zone should be restored with tree plantings, and a cattle crossing should be installed to limit grazing in and around the stream channel.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: 14b

Problem Description: The Borough identified erosion as a problem for the steel girder bridge which conveys a stream beneath Dempsytown Grisham Road (T302).

Photos:

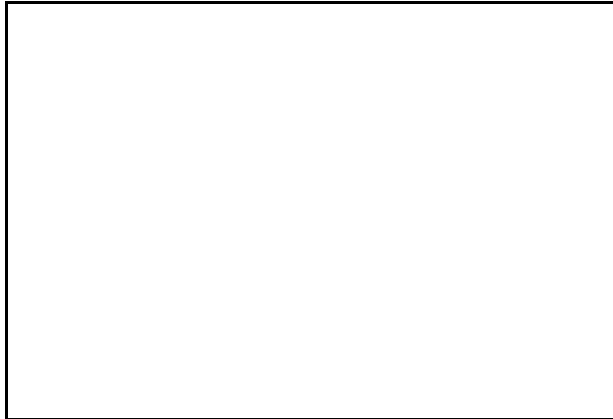
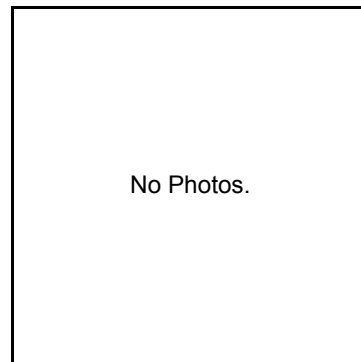


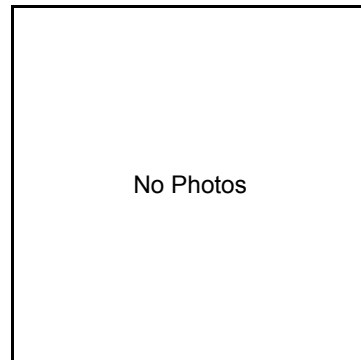
Photo Description:



No Photos.



Photo Description:



No Photos

Conceptual Solution:

Streambank rehabilitation along the streambanks

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O4a

Problem Description: Minor erosion and debris in the stream channel, and some erosion in the shoulder of T574 (Shreve Road) above the structure.

Photos:



Photo Description:

View of upstream face of a concrete box culvert, which carries T574 (Shreve Road) over a stream.



Photo Description:

View of the downstream face of the box culvert

Conceptual Solution:

The Borough is permitted to maintain the channel upstream and downstream of a road crossing for a distance of 50' without the need for a permit from DEP. Also, it may be necessary to place rock and gravel in the shoulder to rebuild it and prevent future erosion.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O15

Problem Description: The bridge carries T670 (Old Route 8) over a tributary to Oil Creek. Part of the bridge parapet has fallen into the channel. Erosion in the stream channel.

Photos:

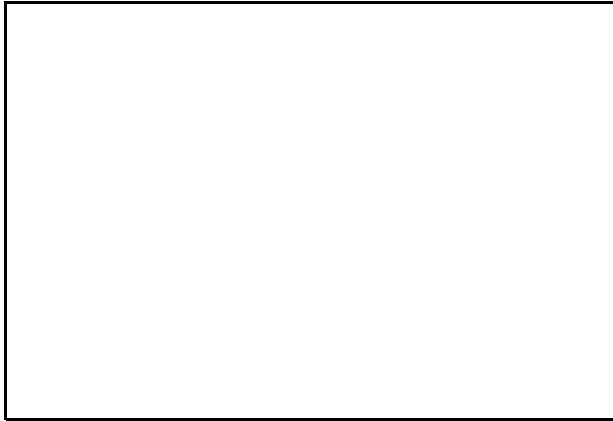


Photo Description:

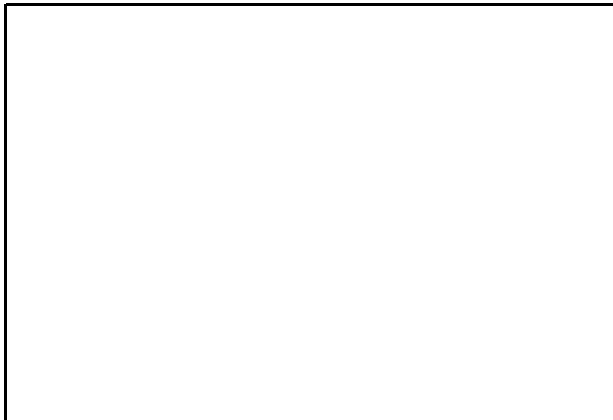
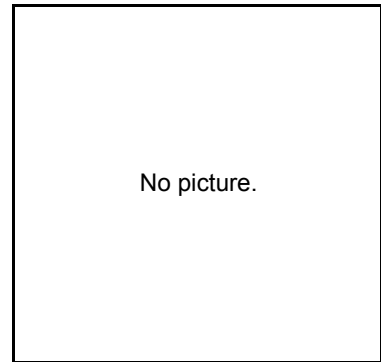
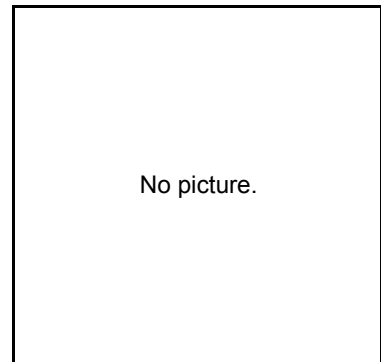


Photo Description:



Conceptual Solution:

Bridge structure is deteriorating, and it may need to be replaced.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O6

Problem Description: Minor erosion was noted along the right bank downstream of the large pipe that carries T578 (Trout Run Road) across the stream.

Photos:



Photo Description:

View of the upstream face of the aluminum pipe arch.



Photo Description:

View of the moderately steep stream channel downstream of the aluminum pipe arch. Note streambank erosion along the right bank.

Conceptual Solution:

Streambank stabilization on the downstream right bank.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O5

Problem Description: Township noted erosion in the stream channel and the streambanks.

Photos:



Photo Description:

View of downstream face of the concrete box culvert that carries Trout Run Road (T578) across the stream.

Photo Description:

No picture.

Conceptual Solution:

Streambank stabilization downstream of the structure.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O2

Problem Description: Erosion to the streambanks and channel.

Photos:



Photo Description:

Downstream view from the large concrete arch culvert that carries Breedtown Road (T663) across the stream.



Photo Description:

Upstream view from the concrete arch culvert. Note erosion along both streambanks.

Conceptual Solution:

Streambank stabilization along both banks upstream of the structure.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: 07

Problem Description: Erosion in the channel and along the streambanks.

Photos:



Photo Description:

Upstream face of the cut stone arch culvert that carries Stone Springhouse Road across the stream.



Photo Description:

Another view of the upstream face of the culvert. Note that the culvert has been extended through the use of a corrugated metal pipe arch on the downstream end.

Conceptual Solution:

Streambank stabilization along both banks downstream of the structure.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O9a

**Problem
Description:**

Streambank erosion has been noted.

Photos:



Photo Description:

Downstream view from the steel beam bridge. Streambank erosion is evident along the left bank.

Photo Description:

No picture.

**Conceptual
Solution:**

Streambank stabilization along the left bank downstream of the structure.

Venango County Act 167 Plan

Municipality: Cherrytree

ID: O9c

Problem Description: Streambank erosion has been identified as a problem by the Borough in the vicinity of the circular smooth steel culvert..

Photos:

Photo Description:

No picture.

Photo Description:

No picture.

Conceptual Solution:

We noted no areas of significant erosion.

Venango County Act 167 Plan

Municipality: Cherrytree **ID:** O9d

Problem Description: The Borough identified erosion as a problem for the stone abutment bridge on Barker Road.

Photos:

Photo Description:

No Photos.

Photo Description:

No Photos.

Conceptual Solution:

Streambank rehabilitation along the streambanks

Venango County Act 167 Plan

Municipality: _____ Cherrytree _____

ID: _____

Problem Description: The Borough identified erosion as a problem for the concrete box culvert which conveys a stream beneath Dempsytown Grisham Road (T302).

Photos:



Photo Description:

Upstream view from the concrete box culvert showing severe erosion on the left streambank. The eroded bank is steeper than a 1:1 slope.

Photo Description:

No Photo.

Conceptual Solution:

Just upstream of the culvert, the left streambank needs rehabilitation, including rock armoring and woody plantings.

Venango County Act 167 Plan

Municipality: Cooperstown

ID: E5

**Problem
Description:**

The Borough has plans to install storm sewers along Maple Lane.

Photos:



Photo Description:

The roadside swales and drive pipes along Maple Lane may be replaced by storm sewers in the future.



Photo Description:

Another view of Maple Lane.

**Conceptual
Solution:**

Richard A. Deiss & Associates, Consulting Engineers have prepared plans for the construction of storm sewers at various locations in the Borough.

Venango County Act 167 Plan

Municipality: Cooperstown

ID: E7

**Problem
Description:**

The Borough has plans to install storm sewers along Reisenman Drive. The roadside swales along Reisenman Drive may be replaced by catch basins and storm sewers.

Photos:

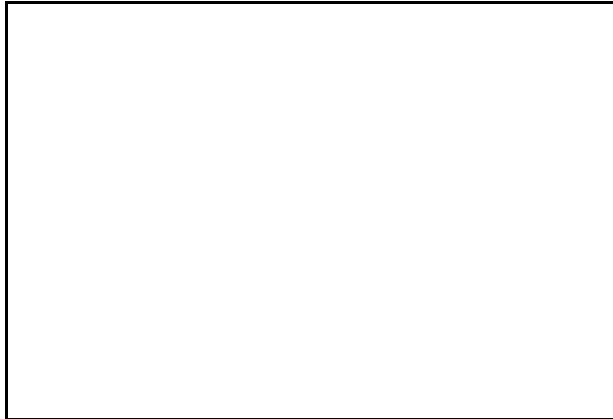
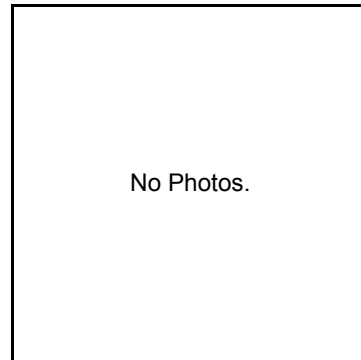
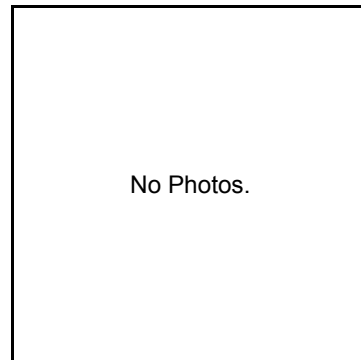
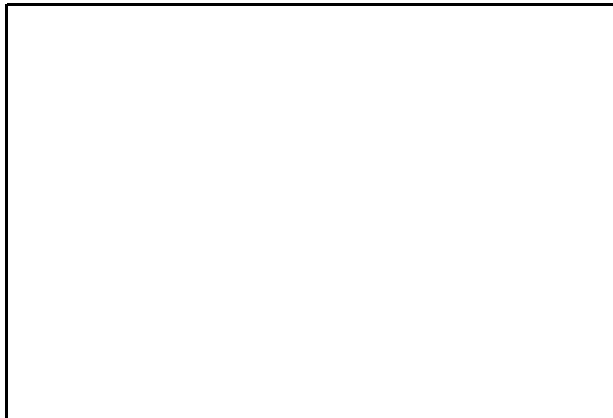


Photo Description:



No Photos.

Photo Description:



No Photos.

**Conceptual
Solution:**

Richard A. Deiss & Associates, Consulting Engineers have prepared plans for the construction of storm sewers at various locations in the Borough.

Venango County Act 167 Plan

Municipality: Cooperstown

ID: E6

Problem Description: The Borough has plans to install storm sewers along Lakeview Drive. The roadside swales along Lakeview Drive may be replaced by catch basins and storm sewers.

Photos:

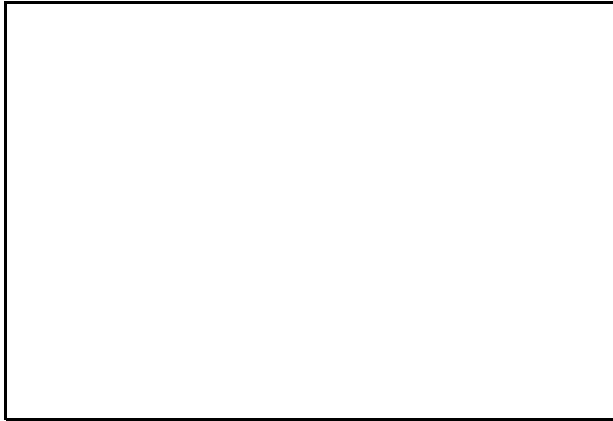


Photo Description:

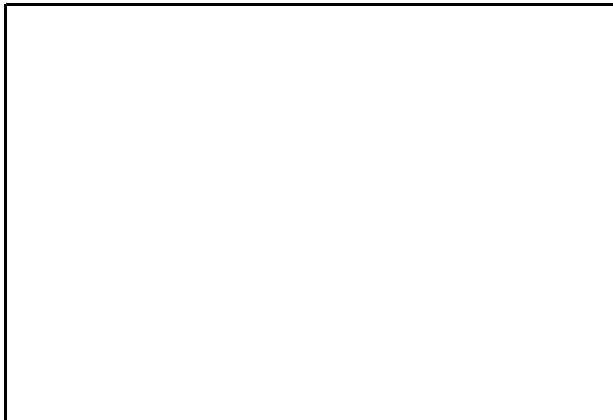
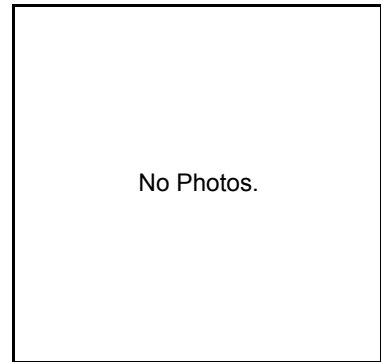
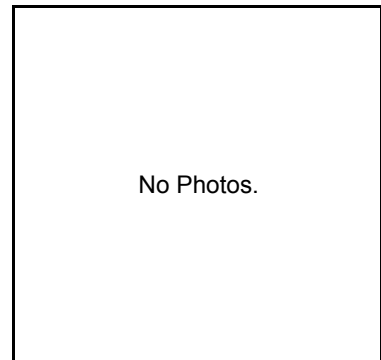


Photo Description:



Conceptual Solution: Richard A. Deiss & Associates, Consulting Engineers have prepared plans for the construction of storm sewers at various locations in the Borough.

Venango County Act 167 Plan

Municipality: Cornplanter

ID: P29 (sheet 1 of 3)

Problem Description: The Township identified Scott Drive as a problem area in need of storm sewers.

Photos:



Photo Description:

Uphill portion of Scott Drive - Looking upstream at the roadside swale along Scott Drive from the intersection of Johnson and Scott.



Photo Description:

Looking downstream at the roadside swale along Scott Drive. The swale is 2' deep with a 1' bottom and 1:1 side slopes. The drive pipes are typically 12". There is a roadside swale on each side of Scott Drive downhill from its intersection with Johnson.

Venango County Act 167 Plan

Municipality: Cornplanter

ID: P29 (sheet 3 of 3)

**Problem
Description:**

Photos:



Photo Description:

Lower portion of Scott Drive (at dead end) - The storm sewer outlets to a wooded area along a previously graded roadbed. The resulting stream cuts across the unpaved road.



Photo Description:

The stream from the Scott Avenue storm sewer system flows to its natural streambed after cutting across the unpaved road.

**Conceptual
Solution:**

Construct inlets and storm sewers along the upper portion of Scott Drive. Tie into the existing storm sewer system at the intersection of Scott Drive and Woodside Avenue.

Venango County Act 167 Plan

Municipality: Cornplanter

ID: P29 (sheet 2 of 3)

Problem
Description:

Photos:



Photo Description:

Middle portion of Scott Drive - At Woodside Avenue, the roadside swales along Scott are piped into a storm sewer.



Photo Description:

Another view of the inlet at the intersection of Woodside Avenue and Scott Drive.

Venango County Act 167 Plan

Municipality: Cornplanter

ID: P30

Problem Description: Two problems identified by the Township: road drainage and streambank reconstruction.

Photos:



Photo Description:

The eroded streambanks of Oil Creek may be submerged by high stream flow.



Photo Description:

The guiderail displacement shown may be evidence of streambank erosion of Oil Creek. Streambank erosion may have caused slope failures in the past.

Conceptual Solution:

The road drainage problem could be alleviated by installing more cross pipes or a storm sewer system. The streambank erosion problem could be alleviated by streambank rehabilitation measures, including rock armoring and woody plantings.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P35

Problem Description: The Township identified muddy water as a problem where East Sandy Creek discharges into the Allegheny River. Also, sedimentation of the riverbed of the Allegheny River was also identified.

Photos:



Photo Description:

A former railroad bridge across the Allegheny River from its confluence with East Sandy Creek.



Photo Description:

Another former railroad bridge that crosses East Sandy Creek just upstream from its confluence with the Allegheny River.

Conceptual Solution:

Due to relatively high water in the Allegheny River, the problem was not evident on the day we visited the site. When the Allegheny River is low, sediment and from the discharge of Sandy Creek is visible on the streambed of the river downstream of the mouth of Sandy Creek. This condition is typical where streams discharge into larger rivers.

Venango County Act 167 Plan

Municipality: Cranberry

ID: O24 and P32

Problem Description: Sage Run floods during heavy rain events.

Photos:



Photo Description:

Upstream face of the concrete beam bridge that carries the highway over Sage Run.



Photo Description:

Looking upstream from the bridge over Sage Run.

Conceptual Solution:

The bridge may need to be replaced with a larger structure.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P34

Problem Description: The problem with Horse Creek may be ice jams that obstruct flow in the Allegheny River or sedimentation that builds up on the riverbed.

Photos:



Photo Description:

A bridge at the mouth of Horse Creek where it joins the Allegheny River. The bridge is so high that the steel beams probably do not obstruct the flow of Horse Creek.



Photo Description:

Looking upstream at Horse Creek from the bridge. The straight, deep channel appears to have been dredged at some point.

Conceptual Solution:

Upstream development may cause excessive sedimentation in Horse Creek.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P33 (1 of 2)

Problem Description: Halls Run floods during heavy rain events.

Photos:



Photo Description:

Looking downstream from the bridge that carries Meadow Church Road over Halls Run.



Photo Description:

Upstream face of the bridge that carries Meadow Church Road over Halls Run.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P92, P93 (2 of 2)

Problem Description: General Flooding in Lower Two Mile Run. Also, soil erosion was reported at a bend in the river.

Photos:



Photo Description:

Downstream view from the deck of "Harts Bridge."



Photo Description:

Looking upstream at Two Mile Run. Note the rocky fill recently placed along the highway.

Conceptual Solution:

Flood control measures in upstream developed areas may mitigate downstream flooding. It appears that someone may have already placed rock fill material between Two Mile Run and the highway to armor the streambanks against further erosion.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P87 (O23, P31)

Problem Description:

Property floods.

Photos:



Photo Description:

Upstream view of "Cunningham Bridge".



Photo Description:

Looking downstream from "Cunningham Bridge". Note floodwaters in overbanks on left and erosion to fill on right.

Conceptual Solution:

Flood control measures in upstream developed areas may mitigate downstream flooding.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P95, SWP03

Problem Description: General flooding of Two Mile Run may be due to malfunctioning stormwater management pond at upstream commercial properties.

Photos:



Photo Description:

Wal-Mart's stormwater management pond appears to be detaining water properly. The outlet structure is completely submerged at this stage (not shown).



Photo Description:

Outfall from Wal-Mart's stormwater management pond appears to be fairly clean.

Conceptual Solution:

Wal-Mart's pond appears to be functioning.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P95, SWP09, SWP10

Problem Description: General flooding of Two Mile Run may be due to malfunctioning stormwater management pond at upstream commercial properties.

Photos:



Photo Description:

Pond for Cranberry Elementary School. This pond appears to have been recently detaining water. It appears to have been designed to completely dewater after the storm flow has ceased. Lower flows bypass the pond through pipes beneath the basin floor.



Photo Description:

Pond for a housing plan on Emerick Drive. The pond seems to be detaining water to some degree, but trees and brush need to be removed from the basin floor and the breastworks.

Conceptual Solution:

Municipality: Cranberry

ID: P33 (2 of 2)

Problem Description: Halls Run floods during heavy rain events.

Photos:



Photo Description:

Looking downstream from the bridge that carries Zacherl Road over Halls Run.



Photo Description:

Looking upstream from the bridge that carries Zacherl Road over Halls Run.

Conceptual Solution:

Halls Run meanders through a flat, wooded wetland area, and it floods during storms. The low-lying road and bridge should be raised if the Township is concerned about evacuation routes becoming blocked during storms.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P92, P93 (1 of 2)

Problem Description: General Flooding in Lower Two Mile Run. Also, soil erosion was reported at a bend in the river.

Photos:



Photo Description:

Upstream elevation of "Harts Bridge" over Two Mile Run.



Photo Description:

Bridge Deck of "Harts Bridge."

Venango County Act 167 Plan

Municipality: Cranberry

ID: SWP-05, P27, P91, P94 (2 of 2)

Problem Description: General flooding of Two Mile Run may be due to malfunctioning stormwater management pond at upstream commercial properties. The stormwater management pond for Cranberry Mall has been identified as a malfunctioning pond.

Photos:



Photo Description:

Outlet structure for the stormwater management pond for Cranberry Mall. The mall building is shown at the top of the hill.



Photo Description:

Pond outfall for the Cranberry Mall's stormwater management pond.

Conceptual Solution: The above photos were taken after a day of moderate rain, and most of the streams in the area were at or nearing flood stage. The Cranberry Mall's stormwater pond should have been detaining stormwater, but the flow into the pond appears to be roughly equal to the flow leaving the pond. Since it appears that the pond has excess capacity, the outlet structure needs to be redesigned to detain more effectively. Also, the trees and brush need to be removed from the breastworks and bottom of the pond.

Venango County Act 167 Plan

Municipality: Cranberry

ID: P95, SWP01, SWP02

Problem Description: General flooding of Two Mile Run may be due to malfunctioning stormwater management pond at upstream commercial properties.

Photos:



Photo Description:

Pond for "The Woodlands" housing development. The pond seems to be detaining water.



Photo Description:

Pond for Home Depot. The pond seems to be detaining water.

Conceptual Solution:

Venango County Act 167 Plan

Municipality: Cranberry

ID: P95, SWP04, SWP07

Problem Description: General flooding of Two Mile Run may be due to malfunctioning stormwater management pond at upstream commercial properties.

Photos:



Photo Description:

Pond for Tractor supply. The pond seems to be detaining water.



Photo Description:

Pond for Hoss's Restaurant. The pond seems to be detaining water.

Conceptual Solution:

Venango County Act 167 Plan

Municipality: Cranberry

ID: P95, SWP 06, SWP08

Problem Description: General flooding of Two Mile Run may be due to malfunctioning stormwater management pond at upstream commercial properties.

Photos:



Photo Description:

Pond for Holiday Inn Express.
Note that the pond is still configured as a sediment basin, because the site has not been fully stabilized yet. The pond appears to be detaining water.



Photo Description:

Pond for UPMC Hospital. The pond seems to be detaining water.

Conceptual Solution:

Venango County Act 167 Plan

Municipality: Cranberry

ID: SWP-05, P27, P91, P94 (1 of 2)

Problem Description: General flooding of Two Mile Run may be due to malfunctioning stormwater management pond at upstream commercial properties.

Photos:



Photo Description:

The large pipe discharges stormwater into the stormwater management pond for Cranberry Mall.



Photo Description:

The interior of the stormwater management pond for Cranberry Mall. The outlet structure is at the far end.

Venango County Act 167 Plan

Municipality: Emlenton

ID: O25

**Problem
Description:**

The Borough identified the catch basins of Hill Street and 4th Street as a problem.

Photos:



Photo Description:

The lines into and out of this catch basin were cleaned out last fall by a contractor. The outlet for this catch basin runs down the steep hill.



Photo Description:

This catch basin discharges to the above catch basin directly across the street.

**Conceptual
Solution:**

This problem appears to have been resolved by a contractor hired by the Borough.

Venango County Act 167 Plan

Municipality: Emlenton

ID: O25B

Problem Description: The Borough identified the catch basins of Hill Street and 4th street as a problem. This site is approximately 500' down the block from point O25A.

Photos:



Photo Description:

The broken pipe at the top of the hill daylights and discharges water overland. The flow has eroded a trench above the pipe run. The flow appears to be picked up by the catch basin at the bottom of the hill.



Photo Description:

Another view of the failed pipe run.

Conceptual Solution:

The pipe run needs to be replaced.

Venango County Act 167 Plan

Municipality: Emlenton

ID: O26

Problem Description: The open pit appears to be subject to obstruction due to debris and sediment. Also, it could be a safety hazard, because it is fairly close to the street.

Photos:



Photo Description:

Flow from a storm sewer (left) discharges into the basin, and is drained by a larger pipe.



Photo Description:

A steel grate has been mounted at the pipe opening that drains the pit. The purpose of the grate is to prevent large pieces of debris from entering the pipe and clogging it.

Conceptual Solution:

The Borough of Emlenton plans to replace the pit with a large catch basin.

Venango County Act 167 Plan

Municipality: _____ Franklin _____

ID: P3 (CHUB-7)

Problem Description: This is an extension of the CHUB-1 through CHUB-6 problem areas. Chub run has its headwaters on the airport's property, and it flows along Route 8 into the City of Franklin where it occasionally surcharges the storm sewer culverts and causes flooding.

Photos:



Photo Description:

Looking upstream at Chub Run flowing through a concrete-bottomed, stone-walled rectangular channel.



Photo Description:

Looking downstream where Chub Run flows into an underground culvert. This culvert may surcharge during heavy storms.

Conceptual Solution: Chub Run flows through culverts beneath the streets of Franklin from this point to where it discharges into French Creek (see CHUB-8). In order to determine the capacity of the culverts beneath the streets of Franklin, a detailed analysis of the storm sewers needs to be performed. Another option is to perform a watershed analysis and construct flood mitigation devices (such as detention ponds) upstream on Chub Run to decrease the magnitude of the flood peak that reaches the culverts.

Venango County Act 167 Plan

Municipality: Franklin

ID: O17, F90

Problem Description: Monkey Run at Coefield Corners is downstream from another problem area identified in Sugarcreek Borough. The stream is enclosed in a square culvert and conveyed underground to French Creek. The stream may overtop the culvert occasionally.

Photos:



Photo Description:

Monkey Run flows into a culvert at Coefield Corners.



Photo Description:

The culvert appears to make an abrupt bend to the left about 50' downstream of the opening (near the middle of the intersection).

Conceptual Solution:

The existing culvert needs to be analyzed to determine whether or not it is big enough. If clogging of the pipe due to debris is the major problem, a large trash rack could be installed at the entrance to the culvert. The outlet of Monkey Run into French Creek was not located. French Creek may have been too high, submerging the outlet.

Venango County Act 167 Plan

Municipality: Franklin

ID: F91

**Problem
Description:**

The storm system is not adequate to handle heavy storm flows.

Photos:



Photo Description:

A stream flows out of a wooded area and is collected and piped underground.



Photo Description:

The grated catch basins may be susceptible to clogging due to debris.

**Conceptual
Solution:**

The storm sewer piping network needs to be analyzed to determine if it is adequate to handle storm flows. If the flooding problem is caused by the above grates becoming clogged, a new endwall with a trash rack could be installed.

Venango County Act 167 Plan

Municipality: Franklin

ID: F87, P99

Problem Description: Where Davis Run flows beneath River Drive, the City reports flooding due to undersized culverts.

Photos:



Photo Description:

Looking upstream as Davis Run exits a concrete arch culvert.



Photo Description:

Looking downstream as Davis Run flows into a newer concrete arch culvert and flows beneath the Franklin Waste Water Treatment Plant, which experienced major flooding due to Davis Run on August 29, 2006.

Conceptual Solution:

It appears as though the Franklin Waste Water Treatment Plant has installed a new bigger culvert beneath the plant.

Venango County Act 167 Plan

Municipality: Franklin

ID: F88, P98

Problem Description: Smith run causes flooding occasionally. The Joy Mining Machinery plant between 3rd and 7th streets has been flooded in the past. The City suggests that the storm sewers are inadequate to handle storm flows.

Photos:



Photo Description:

Smith Run flows into a culvert near a building owned by the water company. The culverts convey the stream around the water company's facility. Smith Run flows underground to the Joy Mining Machinery plant where it occasionally surcharges the storm sewer system and causes flooding in the plant.

Photo Description:

No photo.

Conceptual Solution: Since Smith Run is completely underground from the water company's property to the Allegheny River, the stream characteristics could not be measured directly. The storm sewer system needs to be surveyed and analyzed to determine which pipe runs are undersized. Then a plan needs to be implemented to upgrade the necessary stormwater facilities. A general stormwater analysis was performed by Wodzianski & Smith Inc. Engineers in May 1996.

Venango County Act 167 Plan

Municipality: Franklin

ID: F89, all Buffalo St. problems (1 of 2)

Problem Description: Residents along Buffalo Street experience flooding due to surface runoff from the wooded hillside behind their homes. Runoff flows off the hillside via a natural swale and is collected in the storm sewer system by a pipe or endwall. The pipe may be undersized, or it may get clogged with sediment.

Photos:



Photo Description:

Stormwater flows off the wooded hillside above Buffalo Street. The stream channel in the woods seems to be clean and stable.



Photo Description:

Stormwater from the hillside is collected by a pipe or endwall. Note that the depression around the pipe was about to be overtopped. The pipe may be undersized or partially plugged by debris.

Conceptual Solution:

The stormwater collection pipe needs to be analyzed to determine if it is adequately sized. If necessary, a larger pipe with an endwall needs to be installed and the downstream storm sewer system needs to be upgraded to handle the discharge. We walked the perimeter of the watershed for this stream, and the entire watershed is wooded except for the three recently-constructed houses that drain to a new stormwater management pond. See point ID# SWP-27.

Venango County Act 167 Plan

Municipality: Frenchcreek

ID: P36 (1 of 2)

Problem Description: General flooding and streambank erosion of T-356 along French Creek Road (T-356). Some cabins along the road have been flooded in the past.

Photos:



Photo Description:

French Creek appears to be at flood stage, so streambank erosion is not apparent.



Photo Description:

Another view of the high waters of French Creek.



Venango County Act 167 Plan

Municipality: Frenchcreek

ID: P36 (2 of 2)

Problem Description: General flooding and streambank erosion of T-356 along French Creek Road (T-356). Some cabins along the road have been flooded in the past.

Photos:



Photo Description:

The high waters of French Creek are causing backwater in the tributary that flows beneath French Creek Road. This photo is looking upstream at the tributary.



Photo Description:

Another tributary to French Creek has surcharged the crosspipe beneath French Creek Road and is flowing over the surface of the road. The water pooling on the right side of the road is the overbank flow of French Creek. The water surface of French Creek is approximately 6" from overtopping the road at this point.

Conceptual Solution:

If the Township is concerned about evacuation routes along French Creek Road, the road should be raised above the flood stage of French Creek, and the tributary crossings should be adequately sized to pass major flood events. Structures built in the floodplain should be expected to get flooded occasionally.

Venango County Act 167 Plan

Municipality: Frenchcreek

ID: P37A (3 of 3)

Problem Description: The unnamed tributary to French Creek has experienced heavier flows recently. Erosion is occurring along the streambanks.

Photos:



Photo Description:

Looking upstream at the outfall for the crosspipe that conveys the unnamed tributary under SR 62.



Photo Description:

Looking upstream (west) at the roadside swale that discharges to the SR 62 crosspipe. The crosspipe also drains a swale that comes from the east, which picks up the airport flow associated with the photos on sheet 1 of 3. The western swale shown in the photo has more base flow and more erosion than the eastern swale. It also picks up stormwater runoff from the other runway at

Conceptual Solution:

The stormwater discharge from the airport stormwater management ponds may be contributing to the erosion problem in the unnamed Tributary. All airport runoff should be studied to determine if the ponds are controlling the runoff adequately.

Venango County Act 167 Plan

Municipality: Frenchcreek

ID: P37 (1 of 3)

Problem Description: According to local residents and Frenchcreek Township, excessive runoff due to the airport's development runs through the residential neighborhood of Mapledale.

Photos:



Photo Description:

View looking upstream at a shallow depression (on private property) that catches some runoff from the airport's property (the mesh fence in the background delineates property owned by the Venango Regional Airport).



Photo Description:

The shallow depression is collected in a 15" plastic pipe and conveyed beneath the entrance to a garage. This photo is looking downstream as the 18" plastic pipe discharges to a swale that flows into a 12" plastic pipe. The outlet of this pipe is unknown. These pipes are on private property.

Conceptual Solution:

Existing drainage structures appear to be on private property, so the Township may not have the authority to upgrade the system. If this is the case, the Township would need to acquire easements or get construction and maintenance easements from each property owner to install any drainage structures.

Venango County Act 167 Plan

Municipality: Frenchcreek

ID: P37A (2 of 3)

Problem Description: The unnamed tributary to French Creek has experienced heavier flows since development at the airport has occurred. Erosion is occurring along the streambanks.

Photos:



Photo Description:

Looking downstream at the unnamed tributary to French Creek that flows out of Mapledale. Note eroded streambanks.



Photo Description:

Another view looking downstream at the unnamed tributary to French Creek.

Venango County Act 167 Plan

Municipality: _____ Jackson _____

ID: P40

Problem Description: Bank erosion is occurring approximately 50 feet upstream of the crossing, which is a 6' high, 17' wide aluminum arch structure.

Photos:



Photo Description:

Looking downstream at Wolf Creek from the crossing of Rodger Road.



Photo Description:

Looking upstream at Wolf Creek. Note the erosion in the yard area of the adjacent property. There is a house on the property approximately 50 feet to the left of this photo.

Conceptual Solution:

Based on the topography of the site, it appears that the floodplain of Wolf Creek is relatively wide in this area. The house associated with this property may be in the floodplain. In order to stop the stream from meandering through the wide floodplain, the streambanks in the yard area need to be excavated to a more moderate slope and armored with rock and woody plantings.

Venango County Act 167 Plan

Municipality: Jackson

ID: P39

Problem Description: Bank Erosion in Sugar Creek near Toploga Road. This problem area is partially in the Borough of Cooperstown.

Photos:

Photo Description:

No Photos.

Photo Description:

No Photos.

Conceptual Solution:

Flow in Sugar Creek appears to be divided in this area. The bank erosion was not evident when we visited the site.

Venango County Act 167 Plan

Municipality: Mineral

ID: P43

Problem Description: Runoff from the hillside is washing out a wall that was constructed to prevent debris from blocking a crosspipe on Reeds Furnace Road.

Photos:



Photo Description:

Deadman wall prevents sediment and debris from collecting on the road. Not shown at the toe of the wall is a 15" crosspipe.



Photo Description:

Downstream end of the 15" crosspipe discharging to Sandy Creek.

Conceptual Solution:

It appears that debris and sediment is collecting behind the deadman wall. Eventually, the debris will begin to overrun the wall and continue to plug the crosspipe. The debris needs to be removed from behind the wall to provide more storage.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41b

Problem Description: General road drainage along Krizon Road. The ditches through this small residential town show signs of erosion.

Photos:



Photo Description:

Looking uphill at a roadside ditch along Krizon Road. Ditches are approximately 2' deep and 2' wide at the bottom.



Photo Description:

Looking downhill at a roadside ditch along Krizon Road. Ditches are approximately 2' deep and 2' wide at the bottom.

Conceptual Solution:

The Township's suggestion is to add cross pipes and runoffs. If cross pipes and runoffs were installed, there would be less stormwater in the ditches, and erosion would be reduced.

Venango County Act 167 Plan

Municipality: Mineral

ID: P43B

Problem Description: Runoff from the hillside is washes debris toward Reeds Furnace Road and blocks a crosspipe.

Photos:



Photo Description:

Looking uphill at a swale through the woods that conveys runoff to the crosspipe.



Photo Description:

Upstream end of the crosspipe. It appears that the Township occasionally cleans sediment from around the pipe to keep it clear.

Conceptual Solution:

Periodic clearing and maintenance of this cross pipe will keep it from becoming plugged with sediment and debris.

Venango County Act 167 Plan

Municipality: Mineral

ID: P42

Problem Description: The wetland area around this crossing of Slatertown Road over an unnamed tributary does not drain well. The soil is saturated year-round, and the wet subgrade makes the road unstable.

Photos:



Photo Description:

Looking upstream at the tributary where it flows beneath Slatertown Road.



Photo Description:

The upstream end of the aluminum pipe arch culvert beneath Slatertown Road.

Conceptual Solution:

In order to stabilize the road, the subgrade should be undercut to remove undesirable material. The excavation should be backfilled with acceptable fill before the road surface is restored. Underdrains could be installed parallel to the road to prevent the subgrade from becoming saturated.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41f

Problem Description: General road drainage along Slatertown Road.

Photos:



Photo Description:

Looking uphill at the upstream end of a crosspipe and the associated ditch that conveys water to it.



Photo Description:

Looking downhill at the same crosspipe.

Conceptual Solution:

If the roadside ditches experience erosion during storms, additional crosspipes would reduce the amount of water in the ditches.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41h

**Problem
Description:**

General road drainage along Henderson Station Road.

Photos:



Photo Description:

Looking uphill at a snow-filled roadside ditch along Henderson Station Road.



Photo Description:

Numerous crosspipes with runoffs have recently been installed along this road.

**Conceptual
Solution:**

If erosion and road flooding continue to be a problem, additional crosspipes would reduce the amount of runoff in the roadside ditches.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41a

Problem Description: General road drainage along Palm Hill Road

Photos:



Photo Description:

Looking downhill at a roadside ditch along Palm Hill Road. The ditches are approximately 2' deep.



Photo Description:

Looking downhill at a roadside ditch along Palm Hill Road. The ditches are approximately 2' deep.

Conceptual Solution:

The Township's suggestion is to add cross pipes and runoffs. If cross pipes and runoffs were installed, there would be less stormwater in the ditches, and erosion would be reduced.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41c

Problem Description: General road drainage along Kimble Hill Road.

Photos:



Photo Description:

Drainage from the road is washing debris onto the surface of the road. Roadside ditches are either clogged with debris and sediment or they do not exist.



Photo Description:

A closer view of the debris that is building up along Kimble Hill Road.

Conceptual Solution:

The roadside ditches need to be cleaned out.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41d

Problem Description: General road drainage along the dirt and gravel road.

Photos:



Photo Description:

Looking downstream at a small tributary that runs off the hillside and flows along the road.



Photo Description:

The small tributary runs through a 15" plastic crosspipe then continues through the wood on the opposite side of the road.

Conceptual Solution:

The 15" cross pipe may be inadequately sized. The tributary area to the pipe needs to be studied, and an appropriately sized pipe needs to be installed. Also, flow from the tributary should be collected in a catch basin or endwall and piped along the road to prevent the stream from eroding the road surface during storm events.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41e

Problem Description: General road drainage along Slatertown Road.

Photos:



Photo Description:

Roadside ditches are shallow and filled with debris and sediment.



Photo Description:

Roadside ditches are shallow and filled with debris and sediment.

Conceptual Solution:

Ditches need to be cleaned out in order to convey runoff to the crosspipes that are already in place. Additional crosspipes could be installed in areas where the existing crosspipes are inadequate.

Venango County Act 167 Plan

Municipality: Mineral

ID: P41g

Problem Description: General road drainage along Gadsby Road.

Photos:



Photo Description:

Poor drainage along Gadsby Road near a gas line crossing.



Photo Description:

Looking uphill at an eroded roadside ditch.

Conceptual Solution:

Additional crosspipes and drainage structures would help prevent erosion.

Venango County Act 167 Plan

Municipality: Mineral

ID: P42b

Problem Description: The wetland area around this crossing of Henderson Station Road over an unnamed tributary does not drain well. The soil is saturated year-round, and the wet subgrade makes the road unstable.

Photos:



Photo Description:

Upstream end of the road crossing. These dual 24" HDPE pipes have recently been installed to convey an unnamed tributary across Henderson Station Road.



Photo Description:

Looking downstream at the tributary as it flows toward a nearby lake.

Conceptual Solution:

In order to stabilize the road, the subgrade should be undercut to remove undesirable material. The excavation should be backfilled with acceptable fill before the road surface is restored. Underdrains could be installed parallel to the road to prevent the subgrade from becoming saturated.

Venango County Act 167 Plan

Municipality: Oakland

ID: P44 (1 of 2)

Problem Description: Davis Road runs alongside the East Branch of Sugar Creek. It periodically gets flooded by Sugar Creek and the Tributaries that cross the road. Also, Sugar Creek is experiencing streambank erosion.

Photos:



Photo Description:

Looking upstream at a tributary that crosses beneath Davis Road.



Photo Description:

Another view looking upstream at the tributary.

Conceptual Solution:

If the Township is concerned about emergency vehicle access during floods, Davis Road should be raised above the flood stage of Sugar Creek and its tributaries.

Venango County Act 167 Plan

Municipality: Oakland

ID: P46

Problem Description: A low-lying dwelling gets flooded near the confluence of Prather Creek and Little Sugar Creek.

Photos:



Photo Description:

Upstream face of steel beam bridge that carries the road over Prather Creek.



Photo Description:

Looking downstream from the bridge over Prather Creek. Note the house in the background. The banks of the Little Sugar Creek can be seen in the far background at the left. The confluence of the two streams is approximately 0.25 miles downstream of the crossing.

Conceptual Solution:

The house has been built in a floodplain, so occasional flooding is to be expected. The Township needs to consider enforcing their floodplain regulations. If no floodplain regulations exist, the Township should incorporate a floodplain policy into their Land Development Ordinance or their Zoning Ordinance.

Venango County Act 167 Plan

Municipality: Oakland

ID: P44 (2 of 2)

**Problem
Description:**

Davis Road runs alongside the East Branch of Sugar Creek. It periodically gets flooded by Sugar Creek and the Tributaries that cross the road. Also, Sugar Creek is experiencing streambank erosion.

Photos:



Photo Description:

Looking downstream at East Branch of Sandy Creek flowing parallel to Davis Road. Note that Davis Road was constructed in the floodplain of the creek.



Photo Description:

Looking upstream at East Branch Sandy Creek. Note streambank erosion along right streambank.

**Conceptual
Solution:**

If the Township is concerned about emergency vehicle access during floods, Davis Road should be raised above the flood stage of Sugar Creek and its tributaries. Also, streambank rehabilitation could be performed at the eroded banks of Sandy Creek.

Venango County Act 167 Plan

Municipality: Oakland

ID: P45

**Problem
Description:**

The Township has expressed concern about the runoff that flows off the property of the Tri-City Speedway property. The owner has constructed multiple ponds to attempt to trap sediment before it leaves the property. This problem area is directly related to ID SWP-21.

Photos:



Photo Description:

Looking upstream at a ditch that conveys the outfall of the clay-collection ponds (see SWP-21) to the PennDOT storm sewers along SR-417. There are ditches along both sides of the driveway. The outfall from the sediment basin (see SWP-21) discharges to a natural stream that runs through the wooded area on the left of this photo.

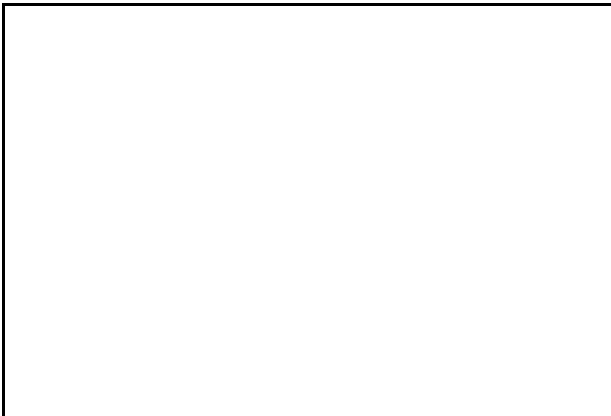
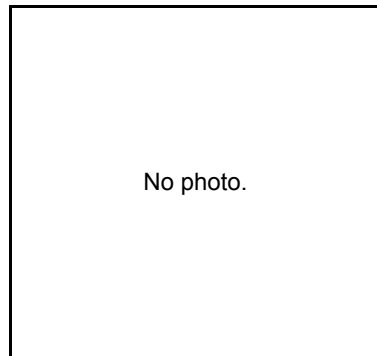


Photo Description:



No photo.

**Conceptual
Solution:**

The property owner appears to be making an effort to prevent excessive sediment from leaving the property. If sedimentation and excessive runoff continue to be a problem the Township should consider contacting PADEP to discuss enforcement of any state regulations.

Venango County Act 167 Plan

Municipality: Oil City

ID: P8 (1 of 2)

Problem Description: Siverly Run has eroded streambanks as it meanders through Hasson Park. Also, flooding may be a problem downstream on Siverly Run.

Photos:



Photo Description:

Wooden footbridge crossing of Siverly Run.



Photo Description:

Looking upstream in Siverly Run from the wooden footbridge. The steep, rocky channel shows little signs of streambank erosion.

Venango County Act 167 Plan

Municipality: Oil City

ID: P6

Problem Description: A house near the intersection of Union Street and Lewis Street has been built adjacent to the streambank of Cornplanter Run. The stream runs along the foundation wall of the house. The house appears to be occupied, but it may flood during large storm events.

Photos:



Photo Description:

Looking upstream at Cornplanter run.



Photo Description:

Looking downstream at the house that was constructed along the streambanks of Cornplanter Run.

Conceptual Solution:

The City recommends house demolition of this property. No structural deficiencies were evident from our inspection from the stream, but condemning the structure may be warranted if it is unsafe for habitation.

Venango County Act 167 Plan

Municipality: Oil City

ID: P15

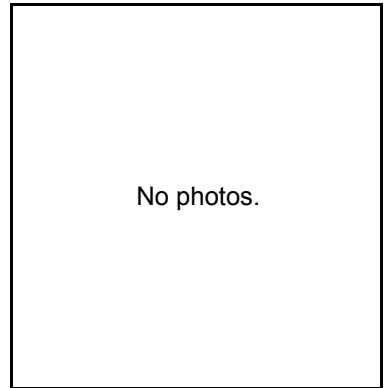
**Problem
Description:**

The City describes the problem as springs along Spring Street. We found an area where stormwater and a spring discharge to a nearby plugged catch basin.

Photos:



Photo Description:



No photos.

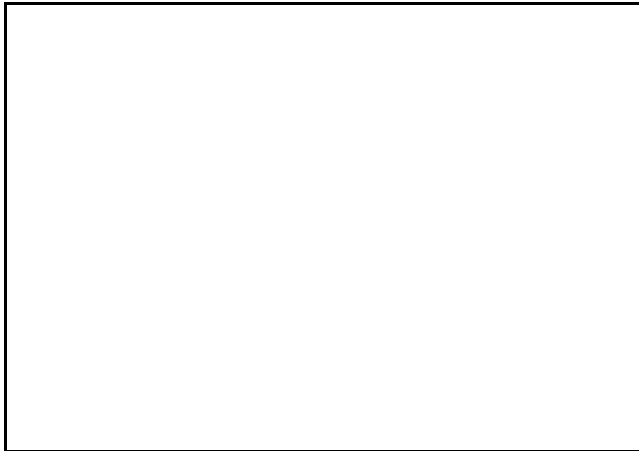
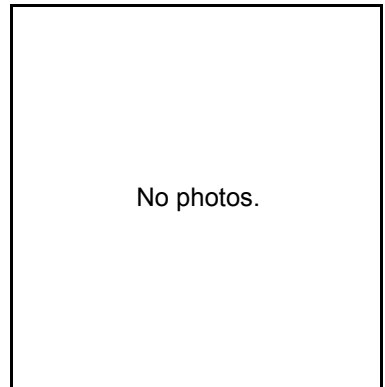


Photo Description:



No photos.

**Conceptual
Solution:**

The catch basin needs to be cleaned out. If the stability of the street is a concern, an underdrainage system would help keep the subgrade dry.

Venango County Act 167 Plan

Municipality: Oil City

ID: P22

Problem Description: The City reports drainage problems due to springs along Summit Street. The swale that runs along Summit Street may overflow its banks and flow down Summit Street.

Photos:



Photo Description:

Looking downhill along Summit Street. A swale runs along the far side of Summit Street. The snowy area in the foreground is a sheet of ice. The springs mentioned by the City may originate on the near side and cause the drainage issues.



Photo Description:

Looking downstream at the swale that runs along Summit Street. There are numerous drive pipes across the swale. Many of the drive pipes are partially blocked with sediment like the one shown.

Conceptual Solution:

The swale that runs along Summit Street may need to be cleaned out. Also, if the springs originate on side of the street opposite the swale, an underdrainage system along the road or in the parking area would help keep the area dry, and it would help maintain the stability of the street.

Venango County Act 167 Plan

Municipality: Oil City

ID: P13

**Problem
Description:**

The City identified drainage problems along Oliver Manor.

Photos:



Photo Description:

Roadside swales along both sides of the street convey stormwater. The swales are mostly invisible due to the snow.



Photo Description:

Another view of a snow-filled swale.

**Conceptual
Solution:**

The City recommends infiltration. If the homeowners were persuaded to install rain gardens, the peak storm flow would be reduced downstream, and lesser rain events would be allowed to infiltrate into the soil (if the soils have good drainage characteristics).

Venango County Act 167 Plan

Municipality: Oil City

ID: P17

**Problem
Description:**

The City indicates that there is a problem with springs along Moran Street.

Photos:



Photo Description:

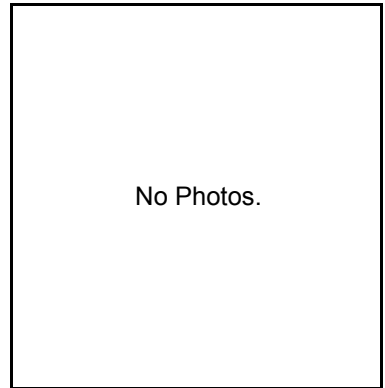
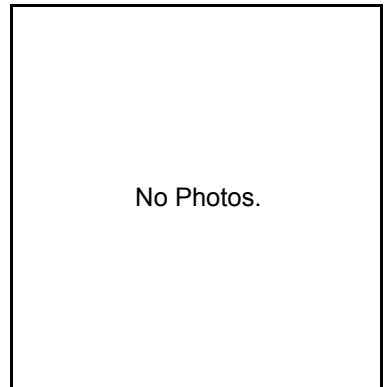
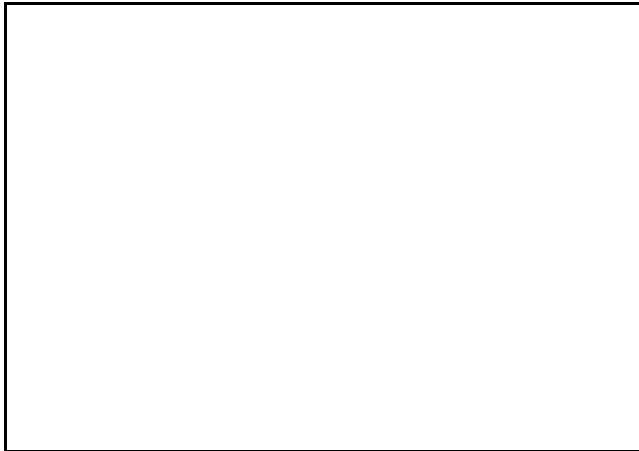


Photo Description:



**Conceptual
Solution:**

We drove around Moran Street, but we saw no signs of springs or other drainage problems.

Venango County Act 167 Plan

Municipality: Oil City

ID: P10 (1 of 2)

Problem Description: Two streams converge at a concrete headwall at the intersection of Willow Street and Alcorn Avenue. The streams occasionally overtop the headwall and flow down the gutters of Alcorn Avenue.

Photos:



Photo Description:

Looking upstream at the larger of the two streams. Note the highly eroded streambanks.



Photo Description:

The streams flow into a catch basin at the concrete headwall. The grate gets plugged with debris, which contributes to the overflow problem.

Venango County Act 167 Plan

Municipality: Oil City

ID: P10 (2 of 2)

Problem Description: Two streams converge at a concrete headwall at the intersection of Willow Street and Alcorn Avenue. The streams occasionally overtop the headwall and flow down the gutters of Alcorn Avenue.

Photos:



Photo Description:

Looking upstream at the smaller of the two streams.



Photo Description:

The smaller stream flows into the catch basin through a small pipe at the bottom of the swale. The pipe may become plugged with debris, which would contribute to the overflow problem.

Conceptual Solution:

Clogging of the grated catch basin is the main problem in this area. A more efficient collection system should be designed. Possibly short pipe runs could be constructed from the swales to the existing catch basin. Endwalls with trash racks could be installed to prevent debris from entering the stormwater system.

Venango County Act 167 Plan

Municipality: Oil City

ID: P7 (1 of 2)

Problem Description: Debris may accumulate and cause surcharging where the streams along the street enter culverts.

Photos:



Photo Description:

Looking upstream from Colbert Avenue. The stream has a steep, rocky streambed, and it flows through a massive debris rack and a concrete channel before flowing beneath the road.



Photo Description:

The upstream face of the concrete culvert (appx. 6' diameter) that carries the stream beneath Colbert Avenue.

Conceptual Solution:

The City noted on their problem area sheet that debris racks helped the problem.

Venango County Act 167 Plan

Municipality: Oil City

ID: P7 (2 of 2)

Problem Description: Debris may accumulate and cause surcharging where the streams along the street enter culverts.

Photos:



Photo Description:

Looking upstream at another steep, rocky streambed with a steel trash rack.



Photo Description:

The upstream face of the 42" pipe culvert that conveys a stream under Colbert Avenue.

Conceptual Solution:

The City noted on their problem area sheet that debris racks helped the problem.

Venango County Act 167 Plan

Municipality: Oil City

ID: P16

Problem Description: The City identified springs along Colbert Avenue as the problem. We found an area where water was puddling on the surface of Colbert Avenue.

Photos:



Photo Description:

No Pictures.

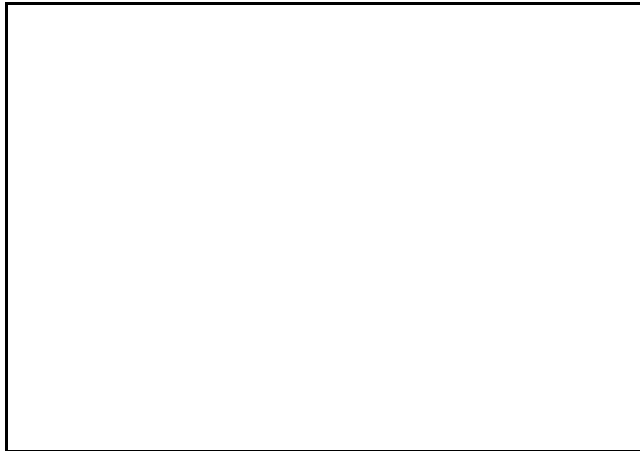


Photo Description:

No Pictures.

Conceptual Solution:

A catch basin could be installed where the water puddles. If the stability of the street is a concern, an underdrainage system would help keep the subgrade dry.

Venango County Act 167 Plan

Municipality: Oil City

ID: P20

Problem Description: The City identified the problem as springs along Mylan Street. There is an area where water flows off of the hill and into some sort of overgrown drainage structure.

Photos:



Photo Description:

Stormwater and flow from a hillside spring flow into this broken pipe along Mylan Street.

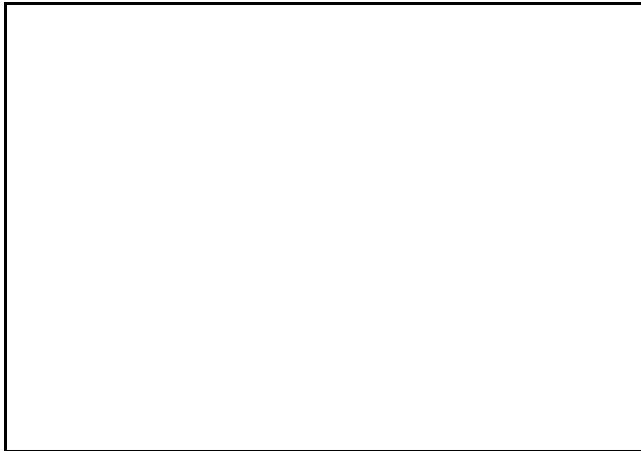


Photo Description:

No photo.

Conceptual Solution:

A catch basin could be installed at the location of the overgrown structure. If the stability of the street is a concern, an underdrainage system would help keep the subgrade dry.

Venango County Act 167 Plan

Municipality: Oil City

ID: P8 (2 of 2)

Problem Description: Siverly Run has eroded its streambanks as it meanders through Hasson Park.

Photos:



Photo Description:

Looking down stream at Siverly Run. Note streambank erosion along the left bank.



Photo Description:

Looking upstream at Siverly Run a quarter mile or so upstream of the wooden footbridge. Note eroded streambanks. This location is north of Hasson Park adjacent to a football field.

Conceptual Solution:

Streambank rehabilitation may be warranted for certain portions of the stream, including excavation of steep banks, and armoring the streambanks with rock and woody plantings. Also, the riparian zone of this stream needs to be restored. The township's suggestion of constructing a pond to slow runoff would also be an option to reduce the volume and velocity of the stream during floods. A pond would also reduce any flooding that may occur downstream of the park.

Venango County Act 167 Plan

Municipality: Oil City

ID: P18

Problem Description: The City describes the problem as springs along Plummer Street. We found an area where springs discharge above the cut stone and concrete walls causing ice buildup on the walls and in the gutterline of Plummer Street.

Photos:



Photo Description:

Looking uphill along Plummer Street at the ice falls off the wooded hillside.



Photo Description:

A closer view of the ice falls along Plummer Street.

Conceptual Solution:

Some sort of drainage system above the wall (cutoff swale, underdrain pipe, or a series of catch basins and pipes) would prevent some of the surface/subsurface water from cascading over the wall.

Venango County Act 167 Plan

Municipality: Oil City

ID: P25

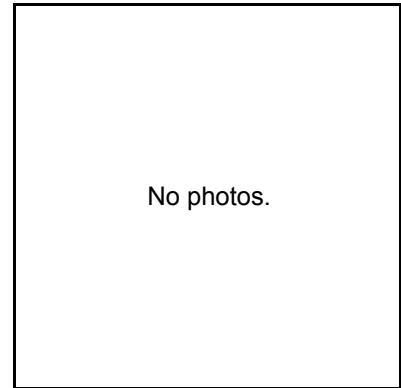
**Problem
Description:**

The City describes the problem as springs along Spruce Street.

Photos:

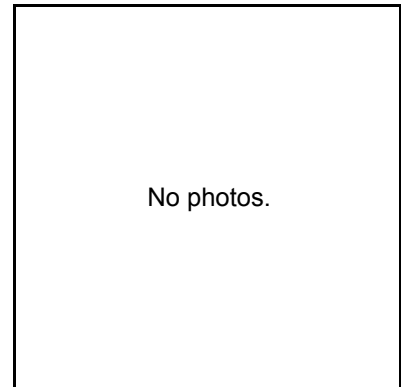
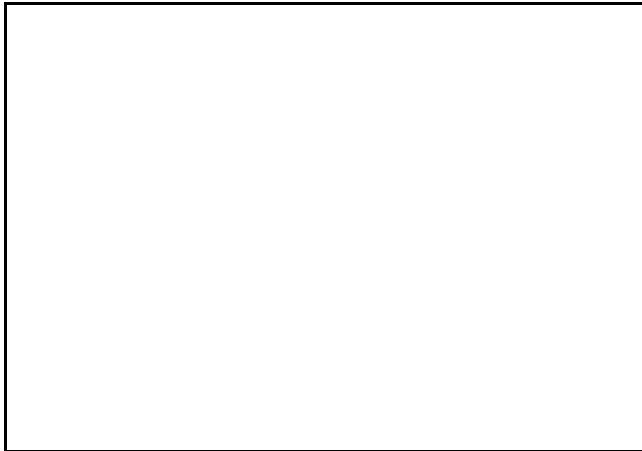


Photo Description:



No photos.

Photo Description:



No photos.

**Conceptual
Solution:**

We found no evidence of springs or any problem areas in the vicinity of Spruce Street. The problem may only be evident during wet weather.

Venango County Act 167 Plan

Municipality: Oil City

ID: P9 (O19)

Problem Description: Cooper Run is enclosed in a culvert beneath the streets of Oil City. It occasionally floods a junkyard, which is located on a flat parcel adjacent to Oil Creek, when it discharges to an open channel for 150 feet or so before flowing through a steel trash rack into a pipe, which runs beneath the junkyard. Also, there is a noticeable foul smell of sewage.

Photos:



Photo Description:

Looking upstream where Cooper run emerges from a concrete box culvert.



Photo Description:

Looking downstream at the trash rack where cooper run flows into a culvert that conveys it beneath the junkyard.

Conceptual Solution:

A properly sized culvert placed along the grade of the existing channel would be less likely to overtop due to improved hydraulics. Also, it would eliminate any debris problem that occurs at the existing trash rack. In order to address the problem of sewage in the stream, the upstream watershed would need to be investigated to determine if any properties are discharging wastewater to the storm sewers.

Venango County Act 167 Plan

Municipality: Oil City

ID: P14

Problem Description: The City indicates that the banks of the Allegheny River at the marina need to be protected.

Photos:



Photo Description:

Looking downstream at the boat launch of the marina.



Photo Description:

Looking upstream from the boat launch. The waters of the River may have been too high to see the streambank erosion that the City mentioned.

Conceptual Solution:

The City indicates that they have applied for grant money to study the problem.

Venango County Act 167 Plan

Municipality: Oil City

ID: P18

Problem Description: The City indicates springs as a problem in this area. We noted a recent coldpatch repair that had failed. It appears to be on a recently-excavated pipe run. There is also ice buildup around the failed patch, so a spring may have been encountered when the pipe trench was excavated.

Photos:



Photo Description:

Looking down Plummer Street at the failed coldpatch street repair. Note the ice buildup in the gutterline of Plummer Street downhill of the patch.



Photo Description:

A closer view of a pothole that has developed in the coldpatch street repair.

Conceptual Solution:

If a spring was encountered beneath Plummer Street, an underdrain system along the gutterline of the street may be able to intercept the groundwater before it gets beneath the pavement.

Venango County Act 167 Plan

Municipality: Oil City

ID: P19

Problem Description: The City indicates that there is a problem with springs along East Eighth Street.

Photos:



Photo Description:

Water flows out of a mostly-submerged white plastic pipe in the yard of the church.

Photo Description:

No Photo

Conceptual Solution:

Storm inlets could be installed in the low areas along the shoulder of East Eighth Street and at the location where water discharges from the white plastic pipe. As an alternative, an underdrain could be installed along the edge of the street to prevent water from saturating the subgrade beneath the pavement. The storm sewers or underdrains could be tied into nearby storm sewers.

Venango County Act 167 Plan

Municipality: Oil City

ID: P21

**Problem
Description:**

The City indicates that there is a problem with springs along Harold Street.

Photos:



Photo Description:

Looking downhill along Harold Street.



Photo Description:

Looking uphill along Harold Street. Note water running down the center of the street.

**Conceptual
Solution:**

Harold Street was built with a V-section to convey stormwater down the center of the pavement. During heavy storm flows, it is likely that stormwater gets deep and overtops the edges of the roadway. Icing of the roadway is probably a problem too. A stormwater network of inlets and pipes would safely convey stormwater beneath the street.

Venango County Act 167 Plan

Municipality: Oil City

ID: P5

Problem Description: A building along Sage Run has been identified as a problem area by the City. We noted a used appliance store that appears to have been built directly adjacent to the stream, and it may become flooded during high water.

Photos:



Photo Description:

Looking upstream at Sage Run from the used appliance store.



Photo Description:

Looking downstream at Sage Run as it flows along adjacent to the used appliance store. A wall has been built

Conceptual Solution:

The City suggests "eliminating building along stream" as an idea for solving the problem. If the building routinely floods during storms or if it acts as an obstruction and causes upstream flooding, property acquisition may be warranted to remove the building from the streambanks.

Venango County Act 167 Plan

Municipality: Oil City

ID: P23

Problem Description: Halyday Street springs.

Photos:



Photo Description:

Stormwater flows out of the excavated hillside along Halyday Street.



Photo Description:

Looking downhill along Halyday Street where flow from the excavated hillside flows along the shoulder of the street.

Conceptual Solution:

The storm sewer network could be extended along the shoulder of Halyday Street to capture the stormwater before it causes icing problems along Halyday Street or degradation of the pavement.

Venango County Act 167 Plan

Municipality: Oil City

ID: P24 (1 of 2)

Problem Description: Dwyer Street springs. Dwyer Street climbs a hill and has a switchback partway up the incline. The lower part of the incline appears to accept runoff from the hillside and has erosion problems on the upstream and downstream shoulders.

Photos:



Photo Description:

Looking uphill along Dwyer Street (above the switchback) where stormwater flows off the road surface and over the shoulder.



Photo Description:

Looking downhill from the shoulder of Dwyer Street where water from the surface of the road flows through the wooded hillside toward the portion of Dwyer below the switchback.

Venango County Act 167 Plan

Municipality: Oil City

ID: P24 (2 of 2)

Problem Description: Dwyer Street springs. Dwyer Street climbs a hill and has a switchback partway up the incline. The lower part of the street appears to accept runoff from the hillside and has erosion problems on the upstream and downstream shoulders.

Photos:



Photo Description:

Looking uphill from the lower portion of Dwyer at an eroded gully where stormwater flows onto the shoulder of the street.



Photo Description:

Looking downhill along Dwyer Street below the switchback. Note the concrete wall on the left and the barriers on the right that have been installed to protect cars from damage due to the eroded roadway.

Conceptual Solution:

A storm sewer system should be installed along Dwyer Street to prevent water from flowing along the shoulders and causing degradation of the roadway.

Venango County Act 167 Plan

Municipality: Plum

ID: P47

**Problem
Description:**

Streambank Erosion downstream of a culvert beneath McKinsey Road.

Photos:



Photo Description:

The downstream end of the smooth steel culvert that conveys a stream beneath McKinsey Road.



Photo Description:

Looking downstream from the crossing. Note streambank erosion on the right bank.

**Conceptual
Solution:**

The streambank should be repaired through streambank rehabilitation, including excavating to a gentle slope and armoring with riprap and woody plantings.

Venango County Act 167 Plan

Municipality: Plum

ID: P49

**Problem
Description:**

The roadside ditches along Acel Road have been eroded, because there is nowhere to discharge the water. A stream flows into the ditch along the right partway down the hill.

Photos:



Photo Description:

Looking downhill along Acel Road. The road slopes to the right, and there is a two-foot deep swale along the right shoulder.

Photo Description:

No Photo.

**Conceptual
Solution:**

One solution is to enlarge the roadside swale and armor it with riprap to prevent further erosion. Alternatively, an agreement could be reached with an adjacent property owner to allow the township to discharge some of the water from the ditch to a low point along the road.

Venango County Act 167 Plan

Municipality: Plum

ID: P48

**Problem
Description:**

The roadside ditches along Knightlanger Road have been eroded, because there is nowhere to discharge the water.

Photos:

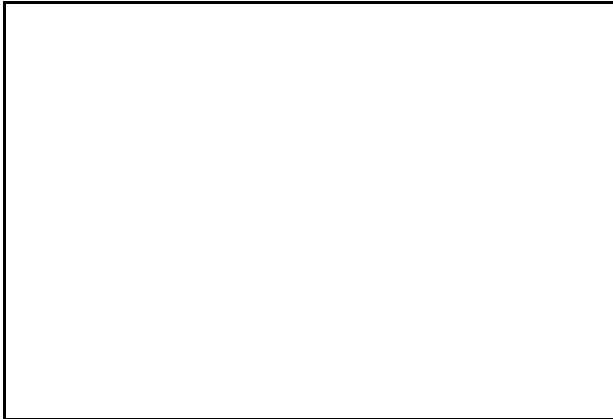


Photo Description:

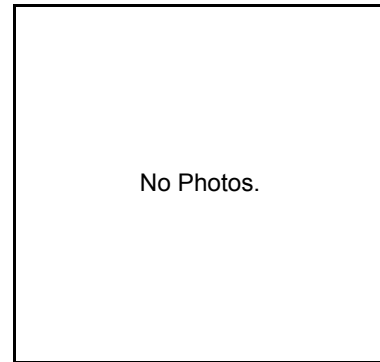
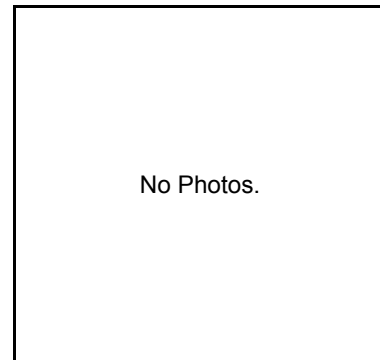


Photo Description:



**Conceptual
Solution:**

The roadside swales should be widened and armored with riprap or runoff pipes should be installed through the wooded area adjacent to the road to reduce the flow in the ditches.

Venango County Act 167 Plan

Municipality: Plum

ID: P50

**Problem
Description:**

The roadside ditches along Krepp Hill Road have been eroded, because there is nowhere to discharge the water.

Photos:



Photo Description:

The roadside ditch along Krepp Hill Road is prevented from discharging away from the road by debris in the runout swale.

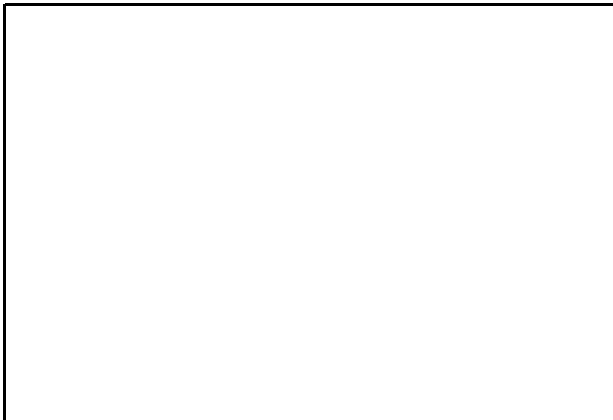


Photo Description:

No Photo.

**Conceptual
Solution:**

There are a few places where the wooded area along the road is lower than the roadside ditches. If crosspipes and runouts were added in this area, the amount of stormwater in the ditches would be reduced. Also, the runout pictured above should be cleaned out so that storm flow is conveyed out of the ditch.

Venango County Act 167 Plan

Municipality: Polk

ID: P77 (1 of 2)

Problem Description: Flooding of Little Sandy Creek along SR 62 upstream of the Polk Cutoff Road bridge, and downstream of the SR62 bridge. There are multiple causes of this flooding.

Photos:



Photo Description:

Looking across the floodplain from the shoulder of SR 62 toward the main channel of Little Sandy Creek (not shown). At this point, the floodwaters are 12 to 18 inches below the elevation of the pavement.



Photo Description:

Looking upstream at Little Sandy Creek from the Polk Cutoff Road bridge. Note the earthen levee on the left. The creek was at flood stage when this picture was taken, and water was actively flowing through the floodplain behind the levee, which had failed in numerous places between the SR62 bridge and the Polk Cutoff Road bridge.



Venango County Act 167 Plan

Municipality: Polk

ID: P73

**Problem
Description:**

The bridge carrying Polk Cutoff Road over Little Sandy Creek needs to have debris cleaned out from under it.

Photos:



Photo Description:

A view of the upstream face of the Polk Cutoff Road bridge. Note that Little Sandy Creek is at flood stage.



Photo Description:

Looking upstream from the bridge deck of the Polk Cutoff Road bridge.

**Conceptual
Solution:**

Debris beneath the bridge deck of the Polk Cutoff Road bridge was not visible since Little Sandy Creek was at flood stage, but it does not appear that the debris causes significant obstruction to streamflow.

Venango County Act 167 Plan

Municipality: Polk

ID: P75

Problem Description: The Borough pointed out that there is a drainage system associated with Polk Center. They indicate that it may have been covered over.

Photos:



Photo Description:

Looking at Polk Center from the intersection of Avante Drive and Lakewood Circle.



Photo Description:

Photo taken from the intersection of Avante Drive and Lakewood Circle. The field shown is the same field that drains to the inlet associated with P74.

Conceptual Solution:

We found no signs of a drainage system in this area.

Venango County Act 167 Plan

Municipality: Polk

ID: P72

Problem Description: SR 62 over Little Sandy Creek. The bridge may become flooded during large storm events.

Photos:



Photo Description:

Downstream face of the bridge carrying SR 62 over Little Sandy Creek. Note that the water surface is approaching the bottom of the steel beams.



Photo Description:

Looking downstream from the deck of the bridge carrying SR 62 over Little Sandy Creek. The creek is above bankfull depth.

Conceptual Solution:

The bridge appears that it may become flooded during large storm events. The bridge may need to be replaced by a larger structure. Also, removing the debris and the failed levee from the floodplain downstream of the bridge may cause less backwater at the bridge.

Venango County Act 167 Plan

Municipality: Polk

ID: P77 (2 of 2)

Problem Description: Flooding of Little Sandy Creek along SR 62 upstream of the Polk Cutoff Road bridge, and downstream of the SR62 bridge. There are multiple causes of this flooding.

Photos:



Photo Description:

This photo and the next one were taken on a day when Little Sandy Creek was below flood stage. This photo is looking upstream at the failed earthen levee between the streambed and SR 65. Note the mature trees that are growing on the levee. This point is appx. 600 feet upstream of the Polk Cutoff Road bridge.



Photo Description:

Looking downstream at large tree trunks and debris that have collected at a bend in the channel of Little Sandy. Note that the levee has been completely obliterated at this point. It continues upstream and downstream of here. This point is approximately 500 feet upstream of the Polk Cutoff Road bridge.

Conceptual Solution:

The earthen levee and debris in the floodplain of Little Sandy Creek cause obstructions to the flow of floodwaters. All debris needs to be removed from the floodplain and all remnants of the failed earthen levee need to be excavated and removed from the floodplain. Where the levee has been excavated (and as necessary along eroded sections of both banks), streambank rehabilitation should be implemented including armoring with riprap and woody plantings. Note that the riparian area through this section appears to be in good condition, so care should be taken to preserve as much existing vegetation as possible.

Venango County Act 167 Plan

Municipality: Polk

ID: P74

Problem Description: Drainage from a field in front of Polk Center drains to an inlet along Bell Street. The outlet pipe from the inlet may be undersized causing stormwater to flow down the street.

Photos:



Photo Description:

Looking up Bell Avenue toward Polk Center. The field on the left drains to the deteriorated inlet in the foreground.



Photo Description:

A close-up view of the deteriorated inlet.

Conceptual Solution:

The outlet from the above inlet is an 18" corrugated metal pipe. It flows along Bell Avenue toward SR 62. The watershed to this inlet should be analyzed to determine if the pipe is properly sized, then the inlet and its outlet pipe need to be replaced.

Venango County Act 167 Plan

Municipality: Polk

ID: P78

Problem Description: The Borough is concerned about debris beneath the McClelland Avenue Bridge. Also, streambank erosion was noted upstream of the bridge.

Photos:



Photo Description:

Upstream face of McClelland Avenue Bridge from the yard of a residential property. Note that the creek is at flood stage. Some turbulence was noted beneath the bridge, but any debris was below the surface of the water.



Photo Description:

Looking downstream from the McClelland Avenue Bridge.

Conceptual Solution:

If debris is causing an obstruction beneath the bridge, the debris should be removed. Where streambank erosion is occurring, streambank rehabilitation should be performed, including excavation of steep slopes and armoring with riprap and woody plantings.

Venango County Act 167 Plan

Municipality: Polk

ID: P76

Problem Description: Inadequate drainage along SR 62.

Photos:



Photo Description:

Downstream end of the plugged 15" concrete cross pipe near the intersection of SR 62 and Niles Road.



Photo Description:

Closer view of the plugged cross pipe.

Conceptual Solution:

The concrete cross pipe needs to be cleaned out to prevent stormwater from flowing across the highway.

Venango County Act 167 Plan

Municipality: Richland

ID: O31

Problem Description: Water overtops T361 (Shotgun Club Road) during floods.

Photos:



Photo Description:

Looking upstream from the culvert that conveys the stream beneath Shotgun Club Road.



Photo Description:

The downstream end of the 5' diameter HDPE culvert.

Conceptual Solution:

There appears to be a debris problem upstream of the culvert. If the pipe routinely becomes clogged with debris during storms, the Township should consider cleaning out the channel periodically. Alternatively, the watershed should be analyzed to determine if the pipe is adequately sized. Dual culverts could be installed in parallel so that the road would not need to be raised for a bigger pipe.

Venango County Act 167 Plan

Municipality: Richland

ID: SWP-28

Problem Description: This point represents the identification of the stormwater management pond for a Chrysler/Jeep dealership.

Photos:



Photo Description:

The outlet structure for the recently-constructed pond is slightly higher than the bottom of the pond. It was likely designed that way to promote infiltration.



Photo Description:

Another view of the stormwater management pond.

Conceptual Solution:

Due to recent wet weather, some stormwater was flowing into this pond, but none was flowing out of the outlet structure. It appears that the stormwater infiltrates through the bottom of the pond, and then flows through the breastwork of the pond and discharges out of the hillside above the highway. If this process continues, the integrity of the embankment may become compromised and the slope may fail.

Venango County Act 167 Plan

Municipality: Rockland

ID: P96

**Problem
Description:**

Runoff from private roads (Wilson Park) cause sediment to discharge into the Allegheny River, and the roadside ditches in Kennerdell are continually becoming deeper due to the high volume of water.

Photos:



Photo Description:

Looking uphill along Watson Street. Note the erosion in the roadside ditch.



Photo Description:

Looking downhill along Watson Street toward the intersection with Main Street. Stormwater is conveyed beneath Main Street then into a swale to the Allegheny River.

**Conceptual
Solution:**

Storm sewers and inlets should be installed along the road to safely convey the stormwater to the River. The watershed above the village of Kennerdell should be analyzed to determine proper pipe sizing and to see if any of the stormwater can be diverted around the residential area directly to the river.

Venango County Act 167 Plan

Municipality: Rockland

ID: P97

Problem Description: Runoff from private roads (Wilson Park) cause sediment to discharge into the Allegheny River, and the roadside ditches in Kennerdell are continually becoming deeper due to the high volume of water.

Photos:



Photo Description:

Looking down a swale where Wilson Avenue enters the Village of Kennerdell. The depth of the swale is approximately 3.5 feet deep at this point.



Photo Description:

Looking uphill along Wilson Avenue. The snow-filled swale on the right side of the road conveys stormwater from the road into Kennerdell. The road and the swale cut most of the runoff from the hillside to prevent it from flowing into the yards of the private properties along the downhill side of the road.

Conceptual Solution:

The swale appears to be moderately eroded. If the Township decides to pave Wilson Ave, a storm sewer system with inlets should be installed. Alternatively, the swale should be stabilized by lining it with riprap. Also, the watershed above the road should be analyzed to determine if some of the flow can be diverted around the village of Kennerdell to reduce the volume of water that flows through this roadside swale.

Venango County Act 167 Plan

Municipality: Rouseville

ID: P51

Problem Description: Water off the hillside above Hiland Avenue is piped beneath the road and it causes erosion problems downstream. Also, the crosspipe may be undersized, causing water to flow across Hiland Avenue.

Photos:



Photo Description:

Looking uphill from Hiland Avenue at the natural drainage swale that conveys water toward the road.



Photo Description:

Looking downhill from Hiland Avenue at the eroded channel downstream of the crosspipe.

Conceptual Solution:

If flooding of Hiland Avenue is a problem, the watershed needs to be analyzed to determine if the crosspipe is properly sized. The channel downstream of Hiland Avenue needs to be lined to prevent further erosion.

Venango County Act 167 Plan

Municipality: Rouseville

ID: P52

Problem Description: There are multiple locations along Bankson Road where crosspipes are becoming clogged due to erosion of the roadside ditches and the upstream ends of the crosspipes.

Photos:



Photo Description:

The upstream end of a typical crosspipe along Bankson Road.

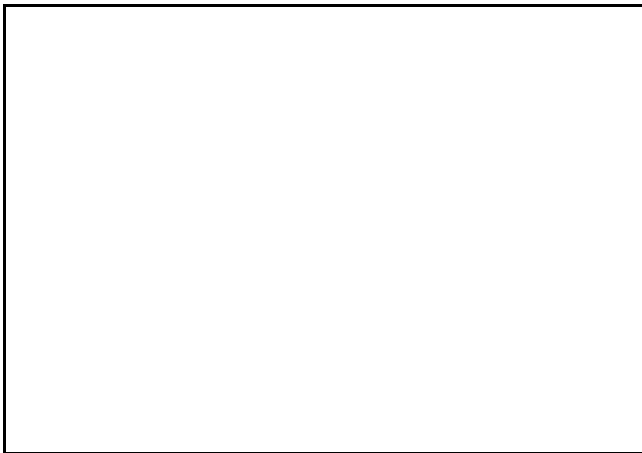


Photo Description:

No Photo.

Conceptual Solution: There are multiple possible solutions to this problem. The Township could add more crosspipes to reduce the volume of flow in the ditches. Lining of the swales with riprap would prevent erosion. Also, steep-slope vegetation could be established in the vicinity of the upstream ends of the crosspipes to stabilize the soil.

Venango County Act 167 Plan

Municipality: Sandycreek

ID: P54 (CHUB-1 AND CHUB-2)

Problem Description: Chub Run flows through Sandycreek Township along the west side of Route 8 from Martino's restaurant to the Franklin city limits. The downstream channel of Chub Run is eroded and it sometimes surcharges the storm sewer system where it flows underground through Franklin.

Photos:



Photo Description:

Downstream end of a 48" CMP beneath a private driveway.



Photo Description:

Looking downstream from the private driveway. Chub Run shows signs of streambank erosion.

Conceptual Solution:

The watershed of Chub Run needs to be analyzed to determine if flood control measures will improve the flooding and erosion problems downstream in the City of Franklin.

Venango County Act 167 Plan

Municipality: Sandycreek

ID: P53 (2 of 3)

Problem Description: Morrison Run floods the Nightingale property and shows signs of heavy erosion in the stream channel downstream of the concrete arch culvert beneath Route 8.

Photos:



Photo Description:

Eroded streambank just downstream of the arch culvert beneath Route 8.



Photo Description:

Eroded streambanks farther downstream of the Route 8 culvert.



Venango County Act 167 Plan

Municipality: Sandycreek

ID: P53 (1 of 3)

Problem Description: Morrison Run floods the Nightingale property and shows signs of heavy erosion in the stream channel downstream of the concrete arch culvert beneath Route 8.

Photos:



Photo Description:

Downstream end of the concrete arch culvert that conveys Morrison Run beneath the highway embankment for Route 8. Note that a tributary discharges to Morrison Run from along the embankment just downstream of the culvert.



Photo Description:

Looking downstream at Morrison Run from the Route 8 embankment. Morrison Run flows into Sandy Creek approximately a half mile downstream. The far side of the Sandy Creek valley is visible in the background of this photo. The mouth of Morrison Run is adjacent to the retention pond for Voyten Electric (SWP-15).



Venango County Act 167 Plan

Municipality: Sandycreek

ID: P53 (3 of 3)

Problem Description: Morrison Run floods the Nightingale property and shows signs of heavy erosion in the stream channel downstream of the concrete arch culvert beneath Route 8.

Photos:



Photo Description:

More eroded streambanks downstream of Route 8.



Photo Description:

Looking upstream at Morrison Run from Route 8. The stream flows along the highway embankment for the highway (on left) before flowing through the concrete arch culvert.

Conceptual Solution:

A Growing Greener grant has been approved for the construction of flood control measures along Morrison Run.

Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P64

Problem Description: This point is at the location of a gas station that has been torn down. A stream flows beneath the parking lot via a 15" corrugated metal pipe that occasionally becomes surcharged, allowing stormwater to flow onto the highway.

Photos:



Photo Description:

Looking upstream at the stream as it flows toward the paved parking lot.



Photo Description:

Looking downstream. The stormwater flows across the abandoned parking lot and ponds along the highway shown in the background.

Conceptual Solution:

The watershed upstream of the pipe needs to be analyzed to determine if the 15" CMP is properly sized.

Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P60 (1 of 2)

Problem Description: Near the intersection of Route 427 and Route 322 in Wyattville, a stream has been routed through two ponds. Occasionally, the stream floods the ponds and a neighboring field. In the past, the stream has backed up and flowed over Route 322.

Photos:



Photo Description:

Looking downstream at the tributary that flows beneath Route 322 toward Sugar Creek.



Photo Description:

Looking west along Route 322 from Anderson Drive. The interchange with Route 427 is near the center of the image.



Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P65

Problem Description: A pipe culvert beneath Shafer Run Road was identified as a problem area.

Photos:



Photo Description:

The upstream end of the 42" HDPE pipe that conveys the stream beneath Shafer Run Road. The bottom of the pipe is significantly deeper than the bed of the stream.



Photo Description:

The downstream end of the 42" HDPE pipe. Note the large scour hole that has formed where the stream discharges.

Conceptual Solution:

The upstream end of the pipe may be susceptible to clogging (causing the stream to flow over Shafer Run Road) since it is lower than the streambed. In order to prevent clogging, the stream channel upstream of the culvert should be excavated to 6" above the pipe invert. This would facilitate smoother flow into the culvert. Also, riprap should be placed at the outfall to repair the scour hole that has formed. Riprap should also be placed beneath the end of the pipe to add support.

Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P66

Problem Description: The crossing of Keely Road over the West Branch of Twomile Run has been identified as a problem area.

Photos:



Photo Description:

Upstream end of the dual 60" CMP culverts conveying West Branch of Twomile Run under Keely Road.



Photo Description:

Looking downstream at the West Branch of Twomile Run

Conceptual Solution:

The stream shows signs of streambank erosion in this location. Streambank rehabilitation may be warranted, including excavation of the steep slopes, and armoring the streambanks with riprap and woody vegetation.

Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P60 (2 of 2)

Problem Description: Near the intersection of Route 427 and Route 322 in Wyattville, a stream has been routed through two ponds. Occasionally, the stream floods the ponds and a neighboring field. In the past, the stream has backed up and flowed over Route 322.

Photos:



Photo Description:

Looking northwest toward the flooded farm field. The recent rains have caused the tributary to overtop its banks.



Photo Description:

Looking north from Route 322 at the flooded farm field. The ponds that normally convey the flow are located to the right of this image across Anderson Drive.

Conceptual Solution:

The property owner of the land with the ponds, who we met at the site, suggested cutting off the streamflow at the end of Keely Road and channeling it directly to Sugar Creek. Since the tributary is only 500 feet from Sugar Creek, this may have been the historic path of the stream. If not, such a drastic alteration of the hydrology may not be warranted. Regardless, the stream has likely been altered from its natural path by the agricultural land uses in the area. The two ponds should be eliminated, and the riparian zone should be reestablished from Keely Road to Route 322. Also, the culvert beneath Route 322 should be analyzed to determine if it is undersized.

Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P63

Problem Description: Stormwater flows across McCleary Road near the bridge over Warden Run during storm events.

Photos:



Photo Description:

The upstream end of the dual culverts that convey Warden Run beneath McCleary Road. Note that McCleary Road is underwater in front of the Jeep. The water is approximately six inches deep across the road.



Photo Description:

The downstream end of the dual culverts. The CMP arches are approximately eight feet wide and seven feet high. Water was flowing through the culverts at high velocity.

Conceptual Solution:

It appears that Warden Run was confined to its banks upstream of the crossing. The water flowing across McCleary Road appears to be from one or more tributaries that flow off the hillside along the road. There is a 15" CMP culvert beneath the road where it is under water. The pipe is completely submerged on its upstream end. The watershed that flows to the pipe should be analyzed to determine if the pipe is undersized.

Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P61

Problem Description: The Borough of Sugarcreek identified Orr's to Weaver Street as a problem area.

Photos:



Photo Description:

Ponded area along Sugarcreek Drive.



Photo Description:

Another view of the ponding along Sugarcreek Drive.

Conceptual Solution:

Street drainage consisting of inlets and storm pipes would alleviate the ponding problems on Sugarcreek Drive. We also noted a tributary to Sugar Creek behind the houses of the properties along the road. The stream was slow-moving when we visited the site even though the area had experienced recent wet weather. There may be downstream obstructions, or backwater due to Sugar Creek may cause flooding in the tributary.

Venango County Act 167 Plan

Municipality: Sugarcreek

ID: P59

Problem Description: Monkey Run along SR 417 south of Rocky Grove High School is a problem area.

Photos:



Photo Description:

Looking upstream at Monkey Run. Upstream of this point the stream is enclosed in a culvert, but it daylights for 1000 feet or so before being enclosed and discharging into French Creek (see point number O17/F90 in City of Franklin). Near the end of the far culvert, the property owner is experiencing erosion problems.



Photo Description:

There are a few locations along Monkey Run where pipes discharge from Second Avenue (to the east) and flow through eroded channels to the stream.

Conceptual Solution:

If the culverts get surcharged during storms, the Borough should consider extending the stream enclosures to convey the flow more efficiently. Also, the upstream watershed could be analyzed to determine if flood control measures would be warranted.

Venango County Act 167 Plan

Municipality: _____ Utica _____

ID: P69 (1 of 2)

Problem Description: Mill Creek Flooding was identified as a problem area. We investigated a portion of Mill Creek approximately 1000 feet downstream of the French Creek Road bridge.

Photos:



Photo Description:

Looking upstream at Mill Creek from a property along the streambanks. Mill Creek was flowing in the floodplain behind the structure visible on the right side of this picture.



Photo Description:

Looking downstream at Mill Creek from the same property as above.



Venango County Act 167 Plan

Municipality: _____ Utica _____

ID: P68

**Problem
Description:**

Erosion in Mill Creek was identified as a problem by the Borough.

Photos:



Photo Description:

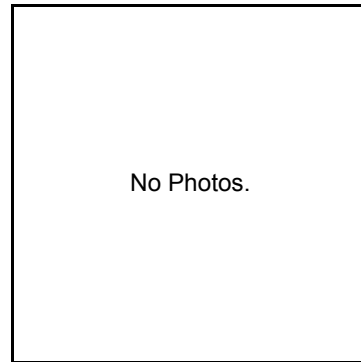
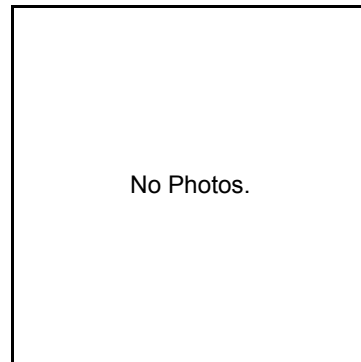
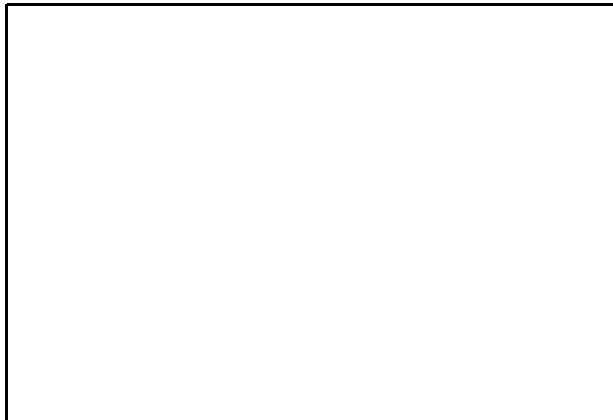


Photo Description:



**Conceptual
Solution:**

Since Mill Creek was at or above bankfull conditions when we visited the Borough, we did not notice any streambank erosion. The stream was flowing at a high velocity at areas P69, P70, and O34, so streambank erosion is a possibility. In areas where streambank erosion is a problem, streambank rehabilitation should be considered. The streambank should be excavated to a mild slope and protected with riprap and woody vegetation.

Venango County Act 167 Plan

Municipality: Utica

ID: P70

Problem Description: The Borough indentified that they are losing the Mill Creek Bridge to erosion.

Photos:



Photo Description:

The upstream face of the steel girder bridge that carries Waterloo Road over Mill Creek. This may or may not be the bridge the Borough was referring to.



Photo Description:

The large riprap along the left abutment (looking downstream) may be washing away little by little during floods.

Conceptual Solution:

The riprap placed along the abutments appears to be preventing the Mill Creek from scouring the soil out from beneath the abutments. If the riprap is being washed away during floods, larger stone could be used or it could be grouted in place with concrete.

Venango County Act 167 Plan

Municipality: Utica

ID: P69 (2 of 2)

Problem Description: Mill Creek Flooding was identified as a problem area. We investigated a portion of Mill Creek approximately 1000 feet downstream of the French Creek Road bridge.

Photos:



Photo Description:

Looking downstream at the overbank flow from Mill Creek. The floodwaters return to the main channel near the white gas line marker in the center of the photo.



Photo Description:

Another shot looking downstream at the overbank flow of Mill Creek. Note that the only access road into the properties (Water Street) was approximately one foot underwater when we visited the site.

Conceptual Solution:

Due to the high water during our site visit, the point where Mill Creek overtopped its banks was not accessible. Extending the levees noted in ID# O34 would help prevent flooding of the low-lying properties in this area. Or a channel could be excavated to drain floodwaters back to the stream channel quicker after the flood event has ended. Since the structures have been constructed in Mill Creek's floodplain, the Borough could consider acquiring the properties and removing the structures as part of a floodplain management program.

Venango County Act 167 Plan

Municipality: Utica

ID: P67

**Problem
Description:**

Flooding of French Creek was identified as a problem by the Borough.

Photos:



Photo Description:

This structure is downstream of the 3rd Street bridge on the left bank. French Creek was somewhat high when we visited the Borough, and a portion of the property has been flooded.



Photo Description:

Looking downstream at French Creek from the 3rd Street bridge. The river is nearing flood stage.

**Conceptual
Solution:**

If any of the structures built along French Creek become flooded regularly, the Borough or the County should consider acquiring the flooded properties as part of a floodplain management program.

Appendix D – Natural Resource Activities Impacting Water Quality

As demonstrated throughout this Plan, land use is a key factor in both the generation and control of stormwater runoff. In Pennsylvania, most types of land use can be regulated by the county or local government through land use ordinances (e.g. zoning). However, the Pennsylvania Municipalities Planning Code (MPC) limits local government control of certain land use categories. Certain types of natural resource activities such as agriculture, forestry, and mining are among the land uses protected by the MPC. Two land use categories that fall within this category were identified by the Plan Advisory Committee, and the municipalities they represent, as land uses that greatly affect the water resources of the county – timber harvesting and oil and gas wells.

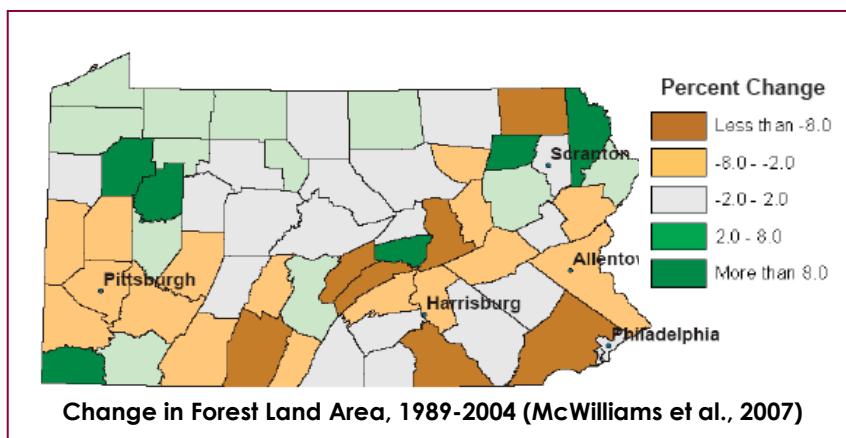


Amendments made to the Pennsylvania Municipalities Planning Code by Act 67 and Act 68 of 2000, limit the regulatory control of municipalities on forestry and timber harvesting. The amendments specify Forestry activities and timber harvesting as "permitted uses by right" in all zoning districts in every municipality. The MPC amendments further clarify that zoning ordinances may not unreasonably restrict forestry activities.

Oil and gas well development in Pennsylvania is regulated by several chapters of the Pennsylvania Code and various state acts. The state's oil and gas laws (Oil and Gas Act – Act 223, Coal and Gas Resource Coordination Act – Act 214, and Oil and Gas Conservation Law – Act 359), as well as environmental protection laws that include the Clean Streams Law, the Dam Safety and Encroachments Act, the Solid Waste Management Act, and the Water Resources Planning Act delegate the authority to regulate these activities to DEP, while limiting the regulatory control of municipalities.

FORESTRY IN PENNSYLVANIA

According to U.S. Forest Service inventories, forest once covered more than 90% (27.3 million acres) of Pennsylvania's land area in the pre-European settlement era (1630s). By the early 1900s, industrial timber harvesting and agricultural land clearing had diminished the forest land base to only 32% (9.2 millions acres). Forest land increased steadily from that point forward and has been relatively stable, at 58% of Pennsylvania's total area, for the last quarter century. Although no significant net change in total area has occurred, there have



Appendix D – Natural Resource Activities Impacting Water Quality

been losses of acreage to development, agriculture and mining. These losses have been offset by agricultural and other lands naturally reverting back to forests. Slightly more than 70% of the nearly 17 million acres of forests in the state are privately owned, with only a small percentage (< 5%) owned by forest product companies. The remaining 30% of the forest land in Pennsylvania is owned by state and federal government entities.

Pennsylvania is known throughout the world as a leading source of high quality hardwood products. The state leads the nation in the production of hardwood lumber (typically more than one billion board feet), accounting for about 10% of the country's annual production (Pennsylvania Forest Products Association, 2008). Pennsylvania also ranks nationally in the production of value added wood products such as millwork and flooring; kitchen cabinets; pallets and containers.

The forest products industry is important in Pennsylvania, where it accounts for 11% of all manufacturing jobs. The forest products industry has a significant impact on the state's economy. In 2005, the state's annual forest product industry sales was \$16.7 billion. The total economic impact of the forest product industry in the state was \$24.7 billion. Three-quarters of this economic impact was generated by sectors depending on locally harvested hardwood timber (Pennsylvania Forest Products Association, 2008). In 2006, there were 2,420 forest product establishments in Pennsylvania, employing 79,910 individuals. In many rural parts of the state the forest products industry is the primary source of economic activity.

FORESTRY IN VENANGO COUNTY

Although it is not a dominant sector, the wood products industry provides important economic opportunities in the county. In 2007, there were 17 wood products establishments employing several hundred people (U.S. Census Bureau, 2008). Timber management encourages the preservation of open space. Through timber harvesting, forests are able to provide landowners with income that can be an incentive for them to maintain woodland on their property. According to a study conducted by the American Farmland Trust, timberland and farmland yield an average of \$3 in taxes for every \$1 in required governmental services, while residential land costs \$1.11 in services for every \$1 collected in tax revenue (The Pennsylvania State University, 2004). Additionally, municipalities with publicly owned State Forests, State Game Lands, and State Parks within their borders receive "in lieu of tax" payments from the Commonwealth.

FORESTRY ACTIVITIES AFFECTING WATER QUALITY

As discussed in *Section IX - Water Quality Impairments and Recommendations*, forestry is one of the basic sources of nonpoint source pollution. On a national level, forestry management activities are estimated to contribute approximately 9 percent of the water quality problems in surveyed rivers and streams (EPA, 1996). Water quality concerns related to forestry were addressed in the 1972 Federal Water Pollution Control Act Amendments and later, more comprehensively, as nonpoint sources under section 208 of the 1977 Clean Water Act and section 319 of the 1987 Water Quality Act.

Forestry is listed as the primary cause for impairment in 0.02% of all non-attaining stream miles in Pennsylvania. There are no stream segments in Venango County listed on the 2009 *Integrated List of All Waters* as non-attaining, with forestry as the primary source of impairment. However, this does not mean that the potential impacts of forestry operations on water quality can be neglected. Local impacts of timber harvesting and road construction can be severe, especially in smaller headwater streams. Many activities associated with forest management can increase the potential for erosion to occur. For this reason, sediment is the primary pollutant of concern associated with forestry activities. Other pollutants include nutrients, organic matter, chemicals

Appendix D – Natural Resource Activities Impacting Water Quality

and others. The fundamental forestry activities with the potential to affect water quality include road construction and use, timber harvesting, mechanical equipment operation, and forest management.

ROAD CONSTRUCTION AND USE

Roads are considered to be the major source of sediment from forested lands. The comparatively small area of roads contributes the vast majority of the total sediment produced from forestry operations. The greatest potential for erosion from roads occurs during road construction and during the first few years afterward. The potential for erosion on forest roads is particularly high because they are exposed to direct rainfall, they are not protected by vegetative cover, road surfaces tend to channelize runoff, and vehicle traffic continually disturb the road surface. Erosion potential is greatly increased when roads are built on cut or fill slopes, when built on steep slopes, and when they are not stabilized with stone or some other means.

Compacted road surfaces also generate increased runoff which compounds erosion problems. Other negative impacts of forest roads include concentrated overland flow on the road surface and in channels, point discharges created by culvert road crossings, and altered subsurface water flow.

TIMBER HARVESTING

Timber harvesting involves many activities that alter the forest landscape. Erosion and sedimentation resulting from these alterations is the primary concern associated with timber harvesting. Facilities used for timber harvesting such as staging (or yarding) areas, skid trails, and access roads are susceptible to increased erosion. These facilities are also at high risk for pollutants such as petroleum products, lubricants, herbicides, pesticides, and other chemicals associated with timber harvesting operations. Many detrimental effects of harvesting are related to the access and movement of vehicles and machinery. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels.

Landscape changes that occur as a result of harvesting can also negatively impact water quality. Timber harvesting disturbs forest litter and changes the vegetative cover which alters the hydrologic response of a watershed. This can lead to increased runoff and erosion. Removing trees from riparian areas disturbs the sensitive ecosystem, exposes the area to pollutants associated with machinery, and reduces shade which can increase water temperatures. Utilizing appropriate timber harvesting and transport practices techniques for a given site can drastically decrease sediment production from these activities.

FOREST MANAGEMENT

Forest management activities such as site preparation for regeneration of harvested sites, prescribed burning, herbicide and pesticide application, and fertilizer application have the potential to negatively affect water quality. Sites that have been intensely harvested can be prepared for regeneration using wheeled or tracked machinery, by prescribed burning, through application of chemicals (i.e. herbicides), or a combination of these methods. These techniques can disturb the soil over large areas, remove vegetation and forest litter, and compact soil. All of these leave the area vulnerable to increased erosion and sedimentation.

FORESTRY POLLUTANTS AND IMPAIRMENTS

Nearly all forestry activities increase the potential for erosion and sediment delivery to streams. Some of these activities have long-term effects (e.g. road building and clear-cutting), while the impacts of others diminish within a few years of the occurrence. Erosion and sedimentation is the primary water quality concern related to forestry activities. Sedimentation is closely related to

Appendix D – Natural Resource Activities Impacting Water Quality

nutrient transport. Nutrients that are immobilized in forest soils are transported along with the sediment to surface waters through erosion. Other water quality pollutants resulting from forestry activities include organic debris, nutrients, chemicals, temperature, and flow variability. These pollutants, how they are generated through forestry activities, and their potential impacts on the county's waters are discussed below.

SEDIMENT

Sediment is often the primary pollutant associated with forestry activities. Accelerated overland erosion often occurs in harvested areas due to vast areas that are destabilized by removal of vegetation. Erosion of these areas discharges sediment and fine silt particles into receiving streams. Sediment transported to waterbodies by erosion can be particularly detrimental to the stream ecosystem, especially to many fish species. Suspended sediments in runoff increase water turbidity limiting the ability of sight-feeding fish to find and obtain food. In addition, the increased turbidity limits the depth to which light can penetrate and adversely affecting aquatic vegetation, increase water temperatures and lower dissolved oxygen concentrations. These effects also compromise recreational values.

When suspended sediment settles, it can fill gravel spaces in streambeds, destroying fish spawning areas and food sources. With large areas of accumulated sediment, the flow capacity of stream channels are reduced. The in stream storage capacity is also reduced, which leads to increasing flooding and decreased water supplies. In addition, nutrients and other pollutants may become adsorbed to sediment particles and be subsequently transported downstream.

ORGANIC DEBRIS

Organic material is an important part of a balanced ecosystem. Organic debris includes plant matter, residual logs, leaves, twigs and other forest litter. This material serves as a source of energy and provides nutrients for plants and animals. This is the primary source of nutrients for headwater streams, where upstream sources of nutrients are limited. Forestry activities can upset the balance of organic material by creating excess debris during timber harvesting or by creating a debris shortage during site preparation for regeneration or by over harvesting in the riparian zone.

Excess organic debris can adversely affect water quality by causing increased biochemical oxygen demand, resulting in decreased dissolved oxygen levels (which are critical for many aquatic species) in watercourses. Logging slash and debris in or near streams can alter stream flows by forming debris dams, and can also redirect flow in the channel, increasing bank cutting and resulting in sedimentation.

NUTRIENTS

Erosion is the primary transport mechanism for nutrient pollution related to forestry activities. Forest soils act as a filter that collects and holds nutrients from decomposing organic matter such as leaves and woody debris. The soil holds many of these nutrients until they are removed by growing plants and used for plant growth. Some nutrients, like nitrogen, are easily dissolved in water and are easily moved throughout the environment. Other nutrients, such as phosphorus, bind to soil particles and are relatively immobile unless relocated by some transport mechanism (e.g. erosion). Excess nutrients in surface waters can result in eutrophication, or a proliferation of plant life, especially algae. Eutrophication causes dissolved oxygen levels to decrease, harming other aquatic organisms.

Appendix D – Natural Resource Activities Impacting Water Quality

CHEMICALS

Chemicals such as herbicides, pesticides, and fertilizers used for forestry operations can contaminate surface water through direct application, transport by surface runoff, or groundwater contamination. These chemicals can poison fish and wildlife or kill unintended plant species. Generally speaking, herbicides, pesticides, and fertilizers pose minimal threat to water quality when handled and applied properly. However, improper application and spills can have severe and long lasting effects. The petroleum products and lubricants used for machinery are of greater concern. These chemicals can be toxic to plants and animals and can contaminate drinking water supplies.

TEMPERATURE

Relatively constant water temperature is important for aquatic biota. When too much vegetation is harvested from the area surrounding stream, the loss of shade can result in increased water temperatures. Temperature increases can be dramatic in smaller (lower order) streams, adversely affecting fish and aquatic invertebrates which have adapted to cooler water temperatures. Suspended solids from sedimentation can also lead to increased stream temperatures as darker particles absorb heat (EPA, 1997). As water temperatures rise, dissolved oxygen levels (which are critical for many aquatic species) decrease. Temperature changes can be a substantial contributor to aquatic life impairments.

STREAM FLOW

The hydrologic response of a watershed can change as a result of timber harvesting. The change resulting from large scale removal of vegetation is often increased stream flow that results from more rapid delivery of runoff to streams. When fewer trees are available to perform the function of evaporation and transpiration, more water becomes available as surface runoff. Increased runoff results in increased stream flow. The amount of stream flow increase is related to the total area harvested, topography, soil type, and harvesting practices (Curtis et al. 1990). Increased stream flow can lead to a variety of problems including scoured channels, erode streambanks, increase sedimentation, and increase peak flows.

FORESTRY MANAGEMENT MEASURES FOR WATER QUALITY

Current forestry management practices and timber harvest techniques have drastically reduced the water quality impacts that occurred from practices of the past century. The water quality impacts of forestry activities can be further minimized by implementing appropriate management measures. Management measures are steps to be taken and guidelines for operations (EPA, 2005). Best Management Practices (BMPs) are specific activities, processes, or technologies designed to serve specific functions, which are used to attain a management measure. These are simple, often low cost, practices and techniques that can be incorporated into forestry operations to diminish impacts to water quality. Additional guidance on BMPs can be found in the following resources developed specifically for Pennsylvania forests:

- Timber Harvest Operations Field Guide for Waterways, Wetlands and Erosion Control (3930-BK-DEP4016), 2009. Pennsylvania Department of Environmental Protection.
- Best Management Practices for Pennsylvania Forests, 2001. The Pennsylvania State University.

A brief overview of EPA's (2005) forestry management measures developed to protect water quality throughout the various phases of forestry activities is presented on the following pages.

Appendix D – Natural Resource Activities Impacting Water Quality

Preharvest Planning

Purpose	Ensure that forestry activities are planned with water quality considerations in mind and conducted in a manner to minimize delivery of nonpoint source pollutants to surface waters.
Target Pollutant(s)	Primarily sediment. Organic matter, thermal modification, nutrients pesticides and toxics are also controlled.
Description	Preharvest planning includes consideration of all stages of a timber harvest including the road system, the harvesting system, the yarding system, and post harvest activities. Site conditions are considered and appropriate BMPs are prescribed to reduce water quality impacts. Contingency plans are developed to reduce the effects of potential problems.

Streamside Management Areas

Purpose	Protect surface waters, the ecologically sensitive areas in riparian zones and wetlands, and maintain the function of floodplains.
Target Pollutant(s)	Sediment, organic debris, and thermal modification. Nutrients, pesticides and toxics are also controlled.
Description	Establish and maintain a buffer zone along surface waters that includes a sufficient number of canopy species, and is wide enough to shade the water, provide bank stability, and filter runoff. Limit forestry activities within the buffer.

Road Construction

Purpose	Reduce erosion and sedimentation which is common during, and immediately after, construction of forestry roads.
Target Pollutant(s)	Sediment. Petroleum products and lubricants.
Description	Design and construction of roads that are planned for the topography, soils, and drainage patterns of a site. Appropriate construction methods and BMPs are used to minimize erosion from high risk areas such as the road surface, steep slopes, water crossings, and runoff conveyance structures (i.e. culverts, ditches, etc.).

Road Management

Purpose	To ensure that management of existing roads maintains their utility and minimizes polluted runoff from roads and road structures.
Target Pollutant(s)	Sediment. Petroleum products and lubricants.
Description	Minimize use during wet weather and thaw conditions. Perform routine maintenance of road surface, stream crossings, and drainage structures. Immediately repair eroding areas and implement BMPs to address problem areas. Close and decommission roads that are no longer needed.

Timber Harvesting

Purpose	Minimize the likelihood of water quality impacts resulting from timber harvesting operations.
Target Pollutant(s)	Sediment, petroleum products.
Description	Follow the plan for timber harvest operations developed during preharvest planning. Conduct operations to avoid sedimentation to the extent practicable. Use appropriate areas for high risk activities such as equipment maintenance, and petroleum and chemical storage and dispensing.

Appendix D – Natural Resource Activities Impacting Water Quality

Site Preparation for Regeneration

Purpose	Minimize erosion and runoff from areas disturbed by site preparation for forest regeneration.
Target Pollutant(s)	Sediment, organic debris, and nutrients.
Description	Select methods of site preparation for regeneration which are suitable for site conditions. Complete site preparation in sensitive areas such as steep slopes and riparian zones using low impact methods and utilizing appropriate BMPs. Leave adequate organic material but protect surface waters from debris and slash material.

Fire Management

Purpose	Minimize nonpoint source pollution and erosion resulting from prescribed burning.
Target Pollutant(s)	Sediment, organic debris, and nutrients.
Description	Use of prescribed fire should be planned and implemented in a manner to protect against excessive erosion. Area to be burned and severity of burn should be prescribed based on site conditions and erosion potential. Appropriate BMPs should be employed to reduce impacts to sensitive areas.

Revegetation of Disturbed Areas

Purpose	Reduce erosion and sedimentation of areas disturbed by forestry activities.
Target Pollutant(s)	Sediment and nutrients.
Description	Reduce erosion and sedimentation by revegetating disturbed areas with appropriate plant species immediately upon completion of earth-disturbing activities. Focus initial efforts on highly susceptible areas such as steep slopes and riparian areas.

Forest Chemical Management

Purpose	Minimize the potential of water pollution by chemicals used for forest management due to environmental transport of chemicals during and after application.
Target Pollutant(s)	Pesticides (i.e. Insecticides, herbicides, and fungicides) and fertilizers.
Description	Risks associated with the use of forest chemicals can be reduced through careful prescription of type and amount of chemicals to be used; delineation of buffer zones; and careful transport and application of chemicals. Spill prevention and contingency plans can reduce the potential impact of spills.

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OIL AND GAS DEVELOPMENT IN PENNSYLVANIA

The petroleum (oil and gas) industry has played a significant role in the history of Pennsylvania. In 1859, Edwin L. Drake drilled one of the first successful oil wells near Titusville, PA. In the years that followed, Venango and Crawford Counties became the center of an industry focused on the drilling, refining, and transporting crude oil and oil products (Harper, 1998). Although not the first natural gas well, the Drake Well (which captured natural gas and piped it to Titusville) is also attributed as the beginning of the natural gas industry in America (NaturalGas.org, 2004). Oil and gas wells are a common part of the landscape throughout much of Pennsylvania. Until recently, the petroleum industry in Pennsylvania had faded to a small fraction of what it had been during its prime.

The Marcellus Shale Formation is a Middle Devonian-age (397.5 – 385.3 million years ago), black, low density, carbonaceous shale that lies nearly a mile or more below the surface of approximately two-thirds of Pennsylvania and large portions of New York, West Virginia, and Ohio as well as small areas of Maryland, Kentucky, Tennessee, and Virginia. Organic rich shales, such as the Marcellus Formation, have been known to hold significant reservoirs of natural gas for more than 75 years (Harper, 2008). Once thought cost prohibitive to extract, recent advances in drilling technology and recent price increases for natural gas have increased interest in this extensive gas reservoir. In 2002, the United States Geological Survey's "Assessment of Undiscovered Oil and Gas Resources of the Appalachian Basin Province" calculated that the Marcellus Shale contained an estimated resource of about 1.9 trillion cubic feet of gas (USGS, 2003).

In 2003, Range Resources – Appalachia, LLC drilled a well in Washington County, Pennsylvania and found a promising flow of natural gas from the Marcellus shale. Borrowing drilling and fracturing techniques that had worked in the Barnett Shale of Texas, they began producing Marcellus gas in 2005 (Harper, 2008). In early 2008, Terry Engelder, a geoscience professor at Pennsylvania State University, and Gary Lash, a geology professor at the State University of New York at Fredonia, "said the Marcellus shale conservatively contains 168 trillion cubic feet of natural gas, but the figure might be as high as 516 trillion cubic feet" (UPI, 2008). The recoverable portion of this reserve is estimated to be around 10 percent of this total. By the end of February 2008 more than 450 suspected Marcellus wells had been permitted in Pennsylvania (Harper, 2008). The stage has been set for an extensive Marcellus Shale gas play in Pennsylvania.

OIL AND GAS ACTIVITIES AFFECTING WATER QUALITY

The potential impacts of oil and gas development on water quality are a concern across the Commonwealth. Of particular concern are: water withdrawals, storm water runoff from construction activities, pollution from drilling processes, groundwater contamination from hydraulic fracturing, and disposal of waste fluids. Water quality concerns related to oil and gas operations are addressed by a variety of federal and state regulations. The 1972 Federal Water Pollution Control Act Amendments and the 1977 Clean Water Act were the first regulations to subject the oil and gas producing industry to direct dealings with a federal agency on environmental protection issues (DOE, 2009a). Other regulations such as the Safe Drinking Water Act (1974) and the Resource Conservation and Recovery Act in (1976) authorize further federal regulation of the oil and gas industry. However, regulation of petroleum activities remains primarily a state responsibility.

In Pennsylvania, oil and gas activities are regulated by several chapters of the Pennsylvania Code and various state acts. The state's oil and gas laws (Oil and Gas Act – Act 223, Coal and Gas Resource Coordination Act – Act 214, and Oil and Gas Conservation Law – Act 359), as well

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as environmental protection laws that include the Clean Streams Law, the Dam Safety and Encroachments Act, the Solid Waste Management Act, and the Water Resources Planning Act give DEP the authority to regulate these activities while limiting the regulatory control of municipalities.

PERMIT	SOURCE/NOTES
Well Drilling Permit and Addendum	Pursuant to the Oil and Gas Act; an application addendum outlining a water management plan for that operation, pursuant to PA Code, Title 25, Chapter 78.11-33.
Earth Disturbance Permit (ESCGP-1)	Required from PA DEP regulating implementation of E&S controls, including SWM, if disturbance >5 acres. E&S plan is required if under 5 acres. PA Code, Title 25, Chapter 102.
Preparedness, Prevention and Contingency (PPC) Plan	The PPC Plan must address the types of wastes generated, disposal methods and a spill prevention plan. Construction and operation of on-site storage impoundments must also be described.
Water Withdrawal Permits	A permit is required from DEP for all withdrawals of surface or ground water. Separate withdrawal permits for projects in the Delaware or Susquehanna Basin or Susquehanna River Basin Commission.
Chapter 105 Obstruction and Encroachment Permit	Permit from DEP for work in a wetland, stream, or body of water. PA Code, Title 25, Chapter 105 (also required under the Oil and Gas Act).
Water Quality Management Permit	Permit if a centralized impoundment will hold fluids other than fresh water (such as drilling or fracturing fluids). The siting, construction, use and closure of temporary pits are regulated under PA Code, Title 25, Chapter 78. Permits are only required if the pit is part of a treatment facility.

Development associated with the Marcellus shale gas play includes construction of new roads, pipelines, compressors, water impoundments, well sites and other facilities. The development of this resource requires the use of large amounts of water and may expand to cover extensive areas. Marcellus shale gas development in Pennsylvania is a matter of local, regional, and national interest. Petroleum activities are listed as the primary cause for impairment in 0.2% of all non-attaining stream miles in Pennsylvania. Recent interest in the Marcellus shale play has the potential to greatly increase this number.

The large volumes of water required to complete a Marcellus Shale natural gas well, and the resulting large. Directional drilling and hydraulic fracturing techniques used to extract gas from the Marcellus shale formation require large volumes of water to complete development of a natural gas well. These approaches require as much as 20 times the water volume as that used in conventional well completions (Harper, 2008). The hydraulic fracturing process for a typical Marcellus shale well uses approximately 3.5 million gallons of water (Harper and Kostelnik, 2010). The resulting large volume of waste water increases the environmental risk of this type of well development.

There are 4.77 miles of stream in Venango County listed on the 2009 *Integrated List of All Waters* as non-attaining, with petroleum activities as the primary source of impairment. This represents just under four percent of all impaired stream miles in the county. However, this does not indicate that water quality impacts from petroleum activities are negligible. Local impacts to surface water and groundwater resulting from petroleum activities can be severe. Oil and gas

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development activities with the potential to affect water quality include construction activities, well development, and gas production.

CONSTRUCTION ACTIVITIES

Construction activities related to well development are the primary concern for impacts to surface water. Gas well construction can involve extensive earth disturbance for access roads, pad sites, and pipelines. For deeper wells the drilling pads alone can create a four to six acre disturbed area (Swistock, 2010). Earth disturbances related to well development present the potential for increased erosion and sedimentation in a manner similar to other construction activities. Well sites in remote locations can present increased risk due to the length of roads and pipelines necessary to support the facility. Other site factors such as slope, proximity to surface water, and soil type can increase the potential for impacts to surface water.

WELL DEVELOPMENT

Once the pad site and supporting facilities have been constructed well drilling begins. This is done with a drilling rig through a multi-stage process in which the wellbore is drilled, cased, and encased with concrete. A typical well can be drilled in 15-30 days if the rig is operating 24-hours a day. Well drilling requires a significant amount of water to lubricate and cool the drill bit and remove the cuttings from the borehole. Large quantities of wastewater are generated during this process. Along with the cuttings, present as suspended solids, the wastewater can contain pollutants such as sodium, chloride, iron, manganese, barium, arsenic, and organics used during the drilling process (e.g. surfactants, detergents, oil, grease, benzene, toluene) (Swistock, 2010).

Once a well has been drilled, a process called hydraulic fracturing, or fracing, is used to create additional permeability in the shale to improve the flow of gas toward the wellbore. Fracing involves pumping a fracturing fluid (typically water-based with other additives to improve performance) into a formation to generate fractures in the target formation to improve release of the natural gas trapped in the rock (DOE, 2010b). Additives used for hydraulic fracturing include sand, oils, gels, acids, alcohols, and various other chemicals. Some portion of the frac water (estimated at 10 to 70 percent) returns to the surface as "flow back" wastewater, with the rest remaining underground.

Various stages throughout well development have the potential to negatively impact water resources. Improperly sealed wells can contaminate drinking water sources; storage, transportation, and disposal of wastewater present opportunities for leaks or spills; additives injected with hydrofracing fluid may contaminate groundwater sources; or methane gas can migrate from gas wells into nearby water supply wells.

GAS PRODUCTION

The production phase of well development generally presents the lowest level of risk to water quality. Once well development is complete water continues to be pumped into the well to improve the flow of natural gas. The return fluids, called production fluids, generally contain high concentrations of salts from ancient underground saltwater deposits. Production fluids also contain some of the pollutants noted in drilling and hydrofracturing fluids.

OIL AND GAS WATER RESOURCE CONCERNS

As previously noted, considerable quantities of water are necessary for the development of a Marcellus Shale gas well. The substantial amount of water utilized presents several challenges in protecting the Commonwealth's water resources. In a report issued by USGS (Soeder and Kappel, 2009), three principal water-resource concerns are noted in regards to Marcellus Shale gas production:

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WATER SUPPLY MANAGEMENT

Water for drilling and hydraulic fracturing of wells typically comes from surface water bodies such as lakes. Groundwater sources, municipal water sources, and re-used process water are also sometimes used for these processes. Some concern exists about where the immense volumes of water necessary to sustain large scale well development will be obtained. Other concerns include what the potential consequences might be for local water supplies and the effects of withdrawing this amount of water when it is needed for drilling activities.

The water volumes necessary to sustain petroleum activities are large; however they generally represent a small percentage of the total water used when considered from a basin-wide surface water budget (DOE, 2010b). To put shale gas water use in perspective, the consumptive use of fresh water for electrical generation in the Susquehanna River Basin is nearly 150 million gallons per day, while the projected total demand for peak Marcellus Shale activity in the same basin is 8.4 million gallons per day (Gaudlip et al., 2008). When these withdrawals are examined at a local level, they represent a much larger percentage of the available resource. Rapid withdrawal of large quantities can have short and long-term effects on a water supply. Surface water withdrawal during dry periods could affect aquatic life, recreational activities, potable water supplies, and other industries.

WATER RESOURCE CONTAMINATION

As discussed in the previous section, petroleum activities have the potential to negatively impact water quality at several stages throughout the drilling and production process. Construction activities necessary to construct access roads, pipelines, and prepare well sites have the potential to cause increased erosion and sedimentation. Access roads and well pad sites are rarely, if ever, fully stabilized which increases the duration of potential erosion problems. Similarly, transporting large amounts of equipment, vehicles, and supplies to remote well sites can damage low capacity rural roads (often constructed of dirt and gravel) and cause accelerated erosion. These effects of these activities can be mitigated through use of common construction BMPs.

Other activities such as well drilling, hydraulic fracturing a well, and gas production all present unique challenges to protecting water quality. The various pollutants found in the process water and flowback fluids used during these activities have the potential to contaminate groundwater supplies or impair surface waters if not handled and disposed of properly. These activities require specialized practices to reduce the risk of contaminating water resources.

WASTEWATER DISPOSAL

The wastewater produced during well development and production is one of the main threats to water quality. The large volumes of liquid produced present logistical and economic challenges for recovery and disposal of the wastewater in a manner that minimizes impacts to water resources. In addition, the pollutants often present in the liquid can require wastewater treatment prior to disposal. Although the percentage of chemical additives in a typical hydrofrac fluid is typically less than 0.5 percent by volume, the quantity of fluid used is so large that the additives in an average three million gallon well development would result in about 15,000 gallons of chemicals in the wastewater (Soeder and Kappel, 2009). In addition to the chemical additives found in hydrofrac fluid, the wastewater may contain a variety of naturally occurring pollutants such as brines, organics, heavy metals, and radionuclides removed from subsurface formations. High concentrations of sodium, chloride, and bromide are often found in brine from well drilling.

Common disposal methods include processing them through wastewater treatment plants (the most common method in Pennsylvania), re-injecting the fluids into the ground, and evaporating

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the liquid and disposing the remaining solids as dry waste. The effectiveness of standard wastewater treatment for processing wastewater is not well understood. In particular, salts and other dissolved solids are not usually removed by standard treatment processes. Re-injecting the wastewater into the ground (shallow re-injection and deep re-injection) may result in groundwater contamination or other unknown problems. The evaporation method is not a very practical technique in the humid climate of Pennsylvania. Further study of these disposal methods and a better understanding of their effects are necessary to effectively protect the water resources of the Commonwealth.

OIL AND GAS MANAGEMENT PRACTICES FOR WATER QUALITY

Many standard practices in the oil and gas industry are currently being implemented in recognition of the need to protect other natural resources while extracting petroleum resources. The water quality impacts of oil and gas activities can be further minimized by implementing appropriate management measures and by utilizing suitable Best Management Practices (BMPs). As presented here, management measures are guidance for operations and steps to be taken that will promote the sound, efficient, and environmentally appropriate development of all oil and gas activities, with a particular focus on Marcellus Shale natural gas developments. BMPs are specific activities, processes, or technologies designed to serve specific functions, which are used to attain a management measure.

Management measures and BMPs for activities associated with oil and gas development can determine what resources may be impacted, the extent of the impacts, and mitigation strategies. Use of the following management measures and BMPs does not replace the need to meet Federal and State requirements, their use (when appropriate) will aid in compliance with the applicable regulations:

- Predevelopment Planning
- Wetland and Riparian Management Areas
- Access Road Construction
- Road Management
- Pipeline Construction
- Well Site Development
- Chemical Management

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Predevelopment Planning

Purpose	Ensure that oil and gas activities are planned with water quality considerations in mind and conducted in a manner to minimize delivery of nonpoint source pollutants to surface waters and groundwater.
Description	A development plan established during the early stages of anticipated development provides the framework for avoiding or minimizing surface disturbance, protecting other resources, mitigating environmental impacts, and alleviating or addressing concerns of landowners and communities. It serves as a tool for comprehensive, coordinated planning to guide strategic development. It can also assist in meeting the requirements of the Clean Water Act, the Clean Air Act, the Endangered Species Act, and other applicable Federal, and State laws.

GUIDANCE: Develop plans to provide a comprehensive description of the characteristics of the area, along with the anticipated nature of the proposed development. Plans should address potential impacts to water quality, existing natural resources, and the potential for habitat fragmentation in sensitive areas where there are high levels of biodiversity, or sensitive and critical habitats.

Planning needs will differ by location and should be applied in different ways, depending on such things as subsurface geology, terrain, and existing and proposed land use. Plans may be simple or complex, depending upon the circumstances, and will need to be customized to fit the site specific conditions for a project. The following items should be included in the plan:

- Identification of land ownership
- Identification of existing and expected surface uses (including number and spacing of wells, roads, pipelines, water disposal and treatment facilities, compression facilities, gathering and transmission pipelines, etc.)
- Identification of existing and required infrastructure and utility corridors
- Map of the area with location of existing facilities (i.e., wells) and potential (optimal) locations for future facilities, including production facilities (well sites, processing units, etc.), roads, and utility corridors. The map should include geographic features such as streams and other water bodies, and special ecosystems, as well as topographic information.
- Identification of opportunities to avoid, reduce, and mitigate adverse impacts
- Identification of regulatory requirements
- Water management plan (strategy)
- Identification of strategies for reclamation of disturbed areas
- Consider a strategy for establishing a baseline and monitoring and steps to apply monitoring information to existing and future actions

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)
BMP 4.3.1. Background Site Factors
BMP 4.3.2. Site Factors Inventory
BMP 4.3.3. Site Factors Analysis

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Wetland and Riparian Management Areas

Purpose	Protect the ecological function and hydrologic features of riparian areas, wetlands, and floodplains.
Description	Establish and maintain a buffer zone along surface waters and wetlands that is wide enough to filter runoff, provide bank stability, and shade the water. Limit oil and gas activities within the buffer.

GUIDANCE: Establish a buffer zone around riparian areas, wetlands, and floodplains. Locate all well pads and other nonlinear facilities outside of the buffer zones.

GUIDANCE: Avoid crossings of wetland and riparian areas by pipelines and roads to the maximum extent practicable. Where crossings cannot be avoided, impacts can be minimized through use of the following measures.

- Develop site-specific avoidance and mitigation plans prior to approval process for all proposed disturbance to wetland/riparian areas, including their buffer areas
- Construct any crossings perpendicular to wetland/riparian areas
- Schedule construction adjacent to wetland areas to minimize the duration of construction activity, and to concentrate such activity during dry conditions, or when the ground is frozen during the winter
- Locate stockpiles outside the buffer areas
- Locate drilling mud pits outside of buffer areas
- Begin reclamation of disturbed wetland/riparian areas as soon as possible after project activities are complete
- Monitor any stream channel for erosion, sedimentation, degradation, and riparian health

Water Quality BMPs:

- Non-Structural (refer to PA Stormwater BMP Manual)

BMP 5.4.1 Protect Sensitive and Special Value Features

BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas

BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

Access Road Construction

Purpose	Reduce erosion and sedimentation which is common during, and immediately after, construction of oil and gas access roads.
Description	Design and construction of roads that are planned for the topography, soils, and drainage patterns of a site. Appropriate construction methods and BMPs are used to minimize erosion from high risk areas such as the road surface, steep slopes, water crossings, and runoff conveyance structures (i.e. culverts, ditches, etc.).

The location and construction of access roads require careful planning. Special attention should be given to steep slopes, surface waters, soils, and other potential hazards. Access roads should be designed with grades between 2 and 10%, located outside buffers of water features, and should have cuts and fills minimized.

GUIDANCE: Utilize existing roads to the maximum extent possible. Locate new roads in areas that will optimize year-round, all-weather access, and minimize surface disturbance and environmental impacts.

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GUIDANCE: Minimize construction of roads where it is operationally feasible and safe. Construct roads to the minimum standard necessary to achieve intended use (i.e. use two-track access roads where possible).

GUIDANCE: Road Construction and Reclamation. Plan, maintain and construct all roads in conformance with road standards. Major access roads to the general development area should be constructed to a higher road standard to avoid excess maintenance caused by poor planning and constructed. Practices that can enhance reclamation include:

- Reclaim and re-vegetate all disturbed surface that will not be used for gas operations in a manner that restores topsoil and minimizes erosion.
- Use re-forestation as a reclamation strategy where forest land was impacted during the development.
- Use only certified and inspected seed that is free of noxious weeds for reclamation/re-vegetation.

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.7.1 Reduce Street Imperviousness	
BMP 5.7.2 Reduce Parking Imperviousness	
• Structural (refer to PA Stormwater BMP Manual)	
BMP 6.4.1 Pervious Pavement with Infiltration Bed	
BMP 6.4.7 Constructed Filter	
BMP 6.4.8 Vegetated Swale	
BMP 6.4.9 Vegetated Filter Strip	
• E&S (refer to PA E&S Pollution Control Manual)	
Sediment Barriers and Filters	Compost Filter Sock, Rock Filter Outlet, Super Silt Fence, Sediment Filter Log, Straw Bale Barrier, Rock Filter, Vegetative Filter Strip
Runoff Conveyance BMPs	Broad-based Dip, Access Road Swale, Ditch Relief Culvert, Turnout
Sediment Capture & Treatment	Construction Entrances, Compost Sock Sediment Trap
Stabilization Methods and Standards	

Road Management

Purpose	To ensure that management of existing roads maintains their utility and minimizes polluted runoff from roads and road structures.
Description	Minimize use during wet weather and thaw conditions. Perform routine maintenance of road surface, stream crossings, and drainage structures. Immediately repair eroding areas and implement BMPs to address problem areas. Close and decommission roads that are no longer needed.

GUIDANCE: Plan access routes for heavy equipment and the high volume of trucks to the site with input from the local municipality and PennDOT.

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GUIDANCE: Consider operational traffic and plan for the long-term operations of the facility considering maintenance as well as potential issues with dust, compaction, and debris, as well as safety.

Water Quality BMPs:

• E&S (refer to PA E&S Pollution Control Manual)	
Sediment Barriers and Filters	
Runoff Conveyance BMPs	
Stabilization Methods and Standards	

Pipeline Construction

Purpose	Reduce erosion and sedimentation during, and immediately after, construction of oil and gas pipelines.
Description	Appropriate design and construction methods are used to minimize erosion from areas disturbed by pipeline construction. BMPs are used in high risk areas such as steep slopes and water crossings.

GUIDANCE: Use existing disturbance corridors whenever possible (ideally following access routes or existing pipeline routes).

GUIDANCE: Locate pipelines in the same trenches, or immediately parallel to, each other. Install pipelines at the same time if possible.

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.4.1 Protect Sensitive and Special Value Features	
BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas	
BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	
BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species	
• E&S (refer to PA E&S Pollution Control Manual)	
Crossings	Roadways, stream, wetlands
Outlet Protection	
Stabilization Methods and Standards	

Well Site Development

Purpose	Minimize the likelihood of water quality impacts resulting from development of oil and gas well sites.
Description	Follow the plan for oil and gas operations developed during predevelopment planning. Conduct operations to avoid sedimentation to the extent practicable. Use appropriate areas for high risk activities such as equipment maintenance, and petroleum and chemical storage and dispensing.

GUIDANCE: Minimize surface disturbance to the maximum extent practicable. Utilize techniques such as drilling multiple wells from the same pad when technically feasible.

GUIDANCE: Remove all equipment not necessary for well operations.

GUIDANCE: Locate well construction activities with the following considerations:

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- Locate well sites in stable, non-erosive soil areas, with grass or brush cover and on relatively level areas that minimize pad construction. Choose sites that avoid steep slopes, unstable soils, and close proximity to streams, floodplains, springs, and wetlands.
- Divert surface runoff from entering the constructed pad site to avoid transporting of pollutants.
- Locate facilities and roads away from occupied dwellings.
- Locate in visually acceptable areas (avoid dwelling view sheds) and paint facilities colors that blend in with the natural environment.
- Locate where safe access can be maintained year round.

Water Quality BMP's:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.5.1 Cluster Uses at Each Site; Build on the Smallest Area Possible	
BMP 5.6.1 Minimize Total Disturbed Area – Grading	
BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas	
BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species	
BMP 5.7.2 Reduce Parking Imperviousness	
BMP 5.9 Source Control	
• E&S (refer to PA E&S Pollution Control Manual)	
Sediment Barriers and Filters	Compost Filter Sock, Rock Filter Outlet, Super Silt Fence, Sediment Filter Log, Straw Bale Barrier, Rock Filter, Vegetative Filter Strip
Runoff Conveyance BMPs	Channels, Top of Slope Berm, Temporary Slope Pipe
Sediment Capture & Treatment	
Outlet Protection	
Stabilization Methods and Standards	
• Structural (refer to PA Stormwater BMP Manual)	
BMP 6.4.1 Pervious Pavement with Infiltration Bed	
BMP 6.4.7 Constructed Filter	
BMP 6.4.8 Vegetated Swale	
BMP 6.4.9 Vegetated Filter Strip	
BMP 6.6.1 Constructed Wetland	
BMP 6.6.2 Wet Pond/Retention Basin	
BMP 6.6.3 Dry Extended Detention Basin	
BMP 6.6.4 Water Quality Filters & Hydrodynamic Devices	
BMP 6.7.1 Riparian Buffer Restoration	
BMP 6.7.2 Landscape Restoration	
BMP 6.7.3 Soil Amendment & Restoration	
BMP 6.7.4 Floodplain Restoration	
BMP 6.8.1 Level Spreader	

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Pollution Prevention

Purpose	Minimize the potential of water pollution caused by potential pollutants used for, or generated by, oil and gas operations.
Description	Risks associated with chemicals and other potential pollutants used for, and generate by, oil and gas operations can be reduced through careful transport, storage and use the substances. Spill Preparedness, Prevention, and Contingency Plans can reduce the potential impact of accidental spills.

GUIDANCE: Prepare a site specific Preparedness, Prevention, and Contingency Plan that identifies potential pollutants used or stored on site, outlines operational procedures to reduce the likelihood of accidental spills, and details a pollution incident response plan to be employed in the event of a spill.

GUIDANCE: Conduct personnel training programs to educate all employees of safe handling and disposal methods of all potential pollutants stored or generated on site. Pollution incident response should also be included in the training.

GUIDANCE: Implement pollution prevention practices when feasible. Use pollution source reduction techniques (i.e. alternative chemicals and additives), reduce or eliminate waste generated through process changes, and use new technologies to remove pollutants from wastewater to reduce the pollution potential of oil and gas activities.

Facility Reclamation and Decommissioning

Purpose	Reduce erosion and sedimentation of areas disturbed by oil and gas activities and minimize long-term impacts of oil and gas activities.
Description	Reduce erosion and sedimentation by stabilizing the work area around active facilities and establishing permanent vegetation on the surrounding area immediately upon completion of earth-disturbing activities. Remove and decommission facilities upon completion of planned use. Restore facility sites to pre-disturbance condition, or better.

GUIDANCE: Reduce facility size to the minimum area required for oil and gas production operations by restoring all areas temporarily disturbed during construction activities. Restoration should include the following:

- Re-contour disturbed areas to be compatible with existing grades.
- Replace topsoil to at least the depth and quality that existed prior to disturbance for final reclamation of the site upon abandonment of the well.
- Re-vegetate disturbed areas using native vegetation and including re-forestation.
- Remove all chemicals, equipment, materials, and waste not necessary for sustaining production from the well pad.

GUIDANCE: Stabilize facilities during operations with crushed stone or other appropriate methods.

GUIDANCE: Remove and decommission facilities as soon as reasonably possible after oil and gas production is completed. Restore the disturbed areas to their pre-disturbance condition, or better, by reshaping the site to the original contour, replacing topsoil, and re-establishing native vegetation.